Marine Fisheries REVIEW

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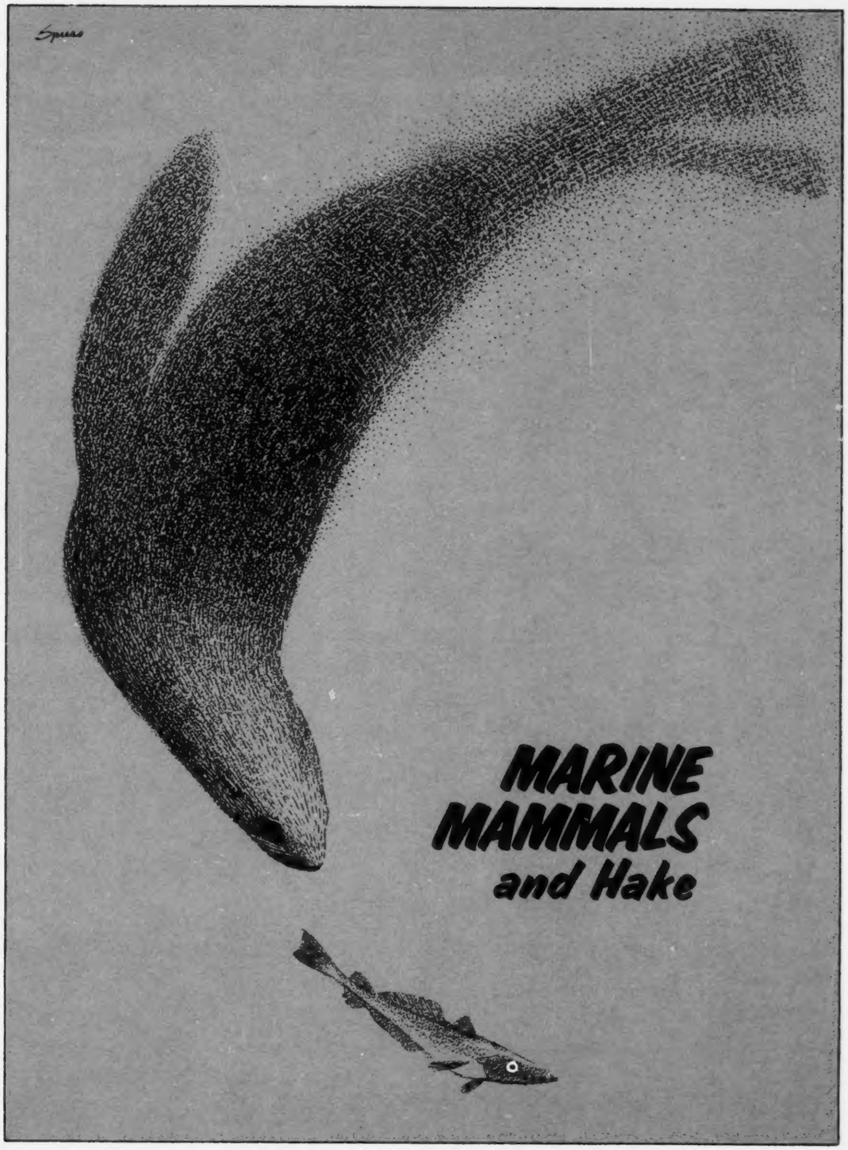

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The importance of Pacific hake, *Merluccius productus*, in the diet of marine mammals is outlined in the article beginning on page 1. Illustration by Harold L. Spiess.

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Interactions of Marine Mammals and Pacific Hake

CLIFFORD H. FISCUS

Introduction

There are from 3 to 11 recognized species of hake (*Merluccius* sp.) worldwide, depending on which authority is consulted. The Pacific hake, *Merluccius productus,* is the species present in the northeastern North Pacific Ocean.

Extensive and detailed information is available on the life history, distribution, and abundance of Pacific hake, with the exception of its early life. The commercial fishery and its development have been carefully followed and documented by scientists of the National Marine Fisheries Service. The importance of hake in the diet of marine mammals and interrelationships between marine mammals and hake is not well known. Information in this paper was obtained from sources either footnoted or listed in the Literature Cited and References sections.

Pacific Hake

Life History, Distribution, and Abundance

Pacific hake, maturing at about 3-4 years of age at about 35-42 cm in length, may live to age 16 but few older than age 9 have been found in unexploited stocks. Mature fish will average different lengths and weights depending on where taken, i.e., mature fish off Washington average 52 cm and 1 kg, but mature fish off northern California average about 47 cm and 0.5 kg. Sizes and ages are stratified latitudinally, and maximum observed length is about 85 cm with females reaching a larger size than males.

Among the prey species utilized by hake off California are red crab, *Pleuroncodes planipes;* euphausiids; shrimp, *Pandalus jordani;* squid, *Loligo opalescens;* northern anchovy, *Engraulis mordax;* juvenile hake, *Merluccius productus;* queenfish, *Seriphus politus;* pink sea perch, *Zalembius rosaceus;* sanddabs, *Citharichthys* sp.; slender sole, *Lyopsetta exilus;* curlfin sole, *Pleuronichthys decurrens;* and clam, *Solemya panamensis*. Gotshall (1969) found 31 different food items in the stomachs of 528 hake taken off northern California from July 1964 to September 1965. Shrimp, *Pandalus jordani,* and krill (euphausiids) composed 62.9 percent (44.4 and 18.5 percent, respectively) of all food found.

Among the prey species utilized by hake off Washington and northern Oregon during May to September, two euphausiids, *Thysanoessa spinifera* and *Euphausia pacifica,* and one species of pandalid shrimp predominated. Fish were of relatively minor importance during the sampling period. Species identified included Pacific herring, *Clupea harengus pallasi;* northern anchovy; eulachon, *Thaleichthys pacificus;* Pacific sand lance, *Ammodytes hexapterus;* and sablefish, *Anoplopoma fimbria*. Traces of squid species were also found.

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ABSTRACT—The biology, feeding habits, seasonal distribution, and range of the Pacific hake, Merluccius productus, *are briefly described. The commercial hake fishery is also discussed. Marine mammals inhabiting the range of the Pacific hake are listed and population estimates are given when known. The known or suspected marine mammal predators on hake are described in detail. The range and seasonal distribution of each species is given and principal prey species (including hake) are discussed. A partial listing of fish which prey on hake is given.*

Hake are found along the Pacific coast from the Gulf of Alaska southward to the Gulf of California; however, they are generally found in numbers sufficient for commercial exploitation only from British Columbia southward to northern Baja California. This species is semipelagic and regularly found near the ocean floor and in midwater.

There are apparently both latitudinal and bathymetric migrations of Pacific hake which occur in about the following manner: Adult hake appear on the continental shelf and slope in April and early May off central and northern California and southern Oregon. They first occur off northern Oregon and Washington in April; however, they are most abundant from northern Oregon to central Washington in June through September in 20-150 fathoms (fm) (37-274 m). From July into September new incursions of adult hake appear from southern Oregon northward to the Vancouver Island area. In late September hake begin to move off the continental shelf into the deeper water of the slope and by December most adults are gone from the area — presumably moving southward to the spawning area, which is located well offshore from Baja California and southern California. Little spawning occurs north of San Francisco. Most spawning apparently occurs between January and April over deep water. Loose spawning aggregations have been identified at depths of 125-255 fm (229-466 m) and 500 fm (914 m).

Little is known about the early life history of Pacific hake. Most hake eggs and larvae have been found at depths of 25-55 fm (46-100 m). Hake, ages 1 and 2, occur over the continental shelf off California. Pacific hake begin to mature by age 3 and most are mature by age 4.

Schools of mature hake over the continental shelf display marked daily vertical movements. These diel movements probably are related to the movement of their euphasiid prey. Their nocturnal movement toward the surface layer at night makes hake more accessible to marine mammals.

The most recent estimate available on population size is from a 1977 sur-

vey by Dark et al[1]. The estimate was about 1,200,000 metric tons (t).

[1]Dark, T. A., M. O. Nelson, J. J. Traynor, and E. P. Nunnallee. 1979. Distribution, abundance, and biological characteristics of Pacific hake, *Merluccius productus*, in the California-British Columbia region during July-September 1977. Unpubl. manuscr., 56 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Commercial Fishery

The U.S. hake fishery has been relatively small and sporadic. Hake have been taken in small quantities in the California animal food fishery since 1953. The U.S. fishery off Oregon and Washington occurred only during 1966-67 when a fish meal processor and fish protein concentrate plant were taking deliveries at Aberdeen, Wash. In 1977 relatively small landings were made at Warrenton, Oreg., and Eureka, Calif., for processing into fillets. The Puget Sound, Wash., fishery persists but is quite small. A major Soviet fishery got underway in 1966 operating from off Vancouver Island to central California and has accounted for the major portion of the catch.

Annual Soviet catches fluctuated between about 103,000 and 167,000 t in 1975 and 1976. Under the Fishery Conservation and Management Act of 1976, it was recommended that the total allowable catch in 1977 off the U.S. west coast (California to Washington) be set at 130,000 t. Of the foreign fleets, only the U.S.S.R. and Poland fished for hake in 1977; they were allocated and took 105,000 and 18,000 t, respectively. Under the Act certain restrictions and regulations apply, and perhaps one of the more significant ones prohibits fishing for hake south of lat. 39°N (about the latitude of Point Arena, Calif.).

References consulted in the Pacific Hake section include: Pereyra and Richards (1969), Alton and Nelson (1970), Grinols and Tillman (1970), Nelson and Larkins (1970), Dark et al. (footnote 1), and Low[2].

Marine Mammals

Species Within Hake Range

Marine mammals known to occur in some portion of the range of Pacific hake in the northeastern North Pacific Ocean are listed in Table 1. One mustelid, 6 pinnipeds, 8 baleen whales and 23 toothed whales, porpoises, and dolphins are found in parts of the hake's range at some season of the year. Some of these species are so rare or their presence in hake habitat so slight that they can be ruled out as having any measurable effect on the hake resource.

Of the 38 marine mammals noted

[2]Low, L. L. 1976. Status of major demersal fishery resources of the northeastern Pacific: Bering Sea and Aleutian Islands. Processed Rep., 116 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Table 1.—Marine mammals inhabiting the range of Pacific hake.

		Relation to hake			
Species[1]	Estimated population in hake range	Competes with	Preys on	Unknown	Data source
California sea lion *(Zalophus californianus)*	80,000 total pop.	—	X	—	Fiscus and Baines (1966); Ainley et al. (1977); Best (1963)
Northern sea lion *(Eumetopias jubatus)*	California, 2,200-2,300 Oregon, 2,000 Washington, 500 British Columbia, 5,000	—	X	—	Spalding (1964)
Northern fur seal *(Callorhinus ursinus)*	500,000	—	X	—	Nor. Pac. Fur Seal Comm. Reps.
Guadalupe fur seal *(Arctocephalus townsendi)*	<2,000	—	—	X	—
Sea otter *(Enhydra lutris)*	Minimal	—	—	X	—
Harbor seal *(Phoca vitulina richardii)*	Minimal	—	X	—	Scheffer (1931) Spalding (1964)
Northern elephant seal *(Mirounga angustirostris)*	50,000	—	X	—	Best (1963)
Gray whale *(Eschrichtius robustus)*	11,000	X	—	—	—
Minke whale *(Balaenoptera acutorostrata)*	No estimate available	X	—	—	—
Brydes whale *(Balaenoptera edeni)*	No estimate available	X	—	—	—
Sei whale *(Balaenoptera borealis)*	9,000 in entire North Pacific	X	—	—	—
Fin whale *(Balaenoptera physalus)*	17,000 in entire North Pacific	X	—	—	—
Blue whale *(Balaenoptera musculus)*	1,700 in entire North Pacific	X	—	—	—
Humpback whale *(Megaptera novaeangliae)*	850 in entire North Pacific	X	—	—	—
Right whale *(Balaena glacialis)*	Minimal (220 in entire North Pacific)	X	—	—	—
Rough-toothed dolphin *(Steno bredanensis)*	Minimal (no estimate available)	—	—	X	—
Bottlenose dolphin *(Tursiops truncatus)*	Minimal (no estimate available)	—	—	X	—
Spinner dolphin *(Stenella longirostris)*	Minimal (1.9 million; only a portion in this area)	—	—	X	—

(Continued on next page)

Table 1. — Continued.

Species[1]	Estimated population in hake range[2]	Relation to hake: Competes with	Preys on	Unknown	Data source
Bridled dolphin (*Stenella attenuata*)	Minimal (3.6 million; only a portion in this area)	—	—	X	—
Striped dolphin (*Stenella coeruleoalba*)	Minimal (248,000; only a portion in this area)	—	—	X	—
Saddleback dolphin (*Delphinus delphis*)	1.4 million; only a portion in this area	—	X	—	Fitch and Brownell (1968); Evans (1976)
Pacific whiteside dolphin (*Lagenorhychus obliquidens*)	No estimate available	—	X	—	Fiscus and Niggol (1965); Best (1963)
Northern right-whale dolphin (*Lissodelphis borealis*)	No estimate available	—	X	—	Fitch and Brownell (1968)
Whitehead grampus (*Grampus griseus*)	No estimate available	—	—	X	—
False killer whale (*Pseudorca crassidens*)	No estimate available	—	—	X	—
Shortfin pilot whale (*Globicephala macro-rhynchus*)	No estimate available	—	—	X	—
Killer whale (*Orcinus orca*)	No estimate available	—	—	X	—
Harbor porpoise (*Phocoena phocoena*)	Minimal (no estimate available)	—	—	X	—
Dall porpoise (*Phocoenoides dalli*)	No estimate available	—	X	—	Loeb (1972); Norris and Prescott, (1961); Best (1963)
Sperm whale (*Physeter macrocephalus*)	300,000 in entire North Pacific	—	X	—	Rice, pers. comm.
Pygmy sperm whale (*Kogia breviceps*)	Minimal (no estimate available; rare)	—	—	X	—
Dwarf sperm whale (*Kogia simus*)	Minimal (no estimate available; rare)	—	—	X	—
North Pacific giant-bottlenose whale (*Berardius bairdii*)	Minimal (no estimate available)	—	—	X	—
Goosebeak whale (*Ziphius cavirostris*)	Minimal (no estimate available)	—	—	X	—
Ginkgo-tooth whale (*Mesoplodon ginkgodens*)	Minimal (no estimate available)	—	—	X	—
Archbeak whale (*Mesoplodon carlhubbsi*)	Minimal (no estimate available; rare)	—	—	X	—
Sabertooth whale (*Mesoplodon stejnegeri*)	Minimal (no estimate available; rare)	—	—	X	—
Densebeak whale (*Mesoplodon densirostris*)	Minimal (no estimate available; rare)	—	—	X	—

[1]From Rice (1977).
[2]Unless qualified in text, population estimates are from the Marine Mammal Protection Act of 1972, Annual Report, April 1, 1977 through March 31, 1978. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., 183 p.

above, we can disregard the 21 species in the following list as unimportant (having no significant impact on the hake resource) because A) they are found only along the edge of the hake habitat, B) their numbers are so small that they are considered rare in this area, C) they are not known to or do not prey on hake, or D) they prey on hake but their impact is considered minimal. The letters in the right column refer to the above.

Species	Relation to hake (see text)
Guadalupe fur seal	B
Sea otter	A
Harbor seal	A-D
Northern elephant seal	D
Rough-toothed dolphin	A
Bottlenose dolphin	A-B
Spinner dolphin	A-C
Bridled dolphin	A-C
Striped dolphin	A-B-C
False killer whale	B
Killer whale	B-C
Harbor porpoise	A
Sperm whale	D
Pygmy sperm whale	B
Dwarf sperm whale	B
North Pacific bottlenose whale	B
Goose beak whale	B
Ginkgo-tooth whale	B
Archbeak whale	B
Sabertooth whale	B
Densebeak whale	B

The harbor seal, *Phoca vitulina richardii*, is fairly abundant along the shore side of the hake range. Hake have been identified in stomachs of harbor seals taken in Puget Sound, Wash., and from "inside" waters of British Columbia (Scheffer and Sperry, 1931; Spalding, 1964). The hake populations in these areas are considered resident and probably do not contribute to the offshore hake population.

The northern elephant seal, *Mirounga angustirostris*, range coincides with that of hake, and although hake have been identified in the stomach contents of dead stranded specimens, most available evidence suggests that elephant seals prey primarily on deepwater fishes and squids (Best, 1963; Huey, 1930; Morejohn and Baltz, 1970).

The killer whale, *Orcinus orca*, is found throughout the range of hake, but hake has not been identified in the few killer whale stomachs examined to date. The number of killer whales

found in offshore hake areas is usually quite small with larger pods probably being more common along the shore side of the hake range.

The sperm whale, *Physeter macrocephalus*, migrates through the range of hake each year; hake were found in the stomachs of 4 of 456 sperm whales taken off San Francisco, Calif., from 1959 to 1970. The importance of hake in the diet of sperm whales is considered minimal (D.W. Rice, Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, Wash., pers. commun.).

The eight species of baleen whales which are found at some season of the year inhabiting the same range as the hake can be classed as competitors for the same food source rather than predators.

The remaining marine mammals are known to prey on hake as indicated by the presence of hake remains in stomachs or because they are considered likely predators as they frequent the same range as hake and have feeding habits similar to known predators.

Species	Known predators	Suspected predators
California sea lion	X	—
Northern sea lion	X	—
Northern fur seal	X	—
Saddleback dolphin	X	—
Pacific whiteside dolphin	X	—
Northern right whale dolphin	X	—
Whitehead grampus	—	X
Shortfin pilot whale	—	X
Dall porpoise	X	—

Known or Suspected Hake Predators

California Sea Lion

The California sea lion, *Zalophus californianus*, ranges along the west coast of Mexico northward to southern British Columbia; its breeding range extends from several of the Gulf of California islands north to San Miguel Island, Calif.—with a scattering of pups being born on islets in San Luis Obispo Bay (Braham, 1974). One pup was born each year for the past 3 years far north of the normal breeding range on Southeast Farallon Island off San Francisco (Ainley et al., 1977). During the breeding season (May-July) almost the entire population is found south of lat. 34°N. Beginning in August there is a migration of a portion of the male population northward, some reaching Vancouver Island. It is estimated that 4,000 males may be found north of California from early fall (September) until spring (May) with approximately 2,500 found off Oregon, 500 off Washington, and 1,000 off southern British Columbia (Bigg, 1973; Mate, 1976b). Recent estimates of the entire population vary.

One estimate gives a population of about 80,000, with 40,000 in Mexican waters and 40,000 in U.S. waters (National Marine Fisheries Service, 1978). A July 1975 aerial survey of the sea lion range yielded counts as follows: Pacific coast (Oregon, California, Mexico) 65,862; Mexico (Gulf of California) 9,428; total =75,290 (Mate, 1977). Another estimate was from a photographic count of the animals (Le Bouef et al.[3]). Sea lion counts or estimates range from 31,731 to 40,000 for California and from 20,000 to 43,653 for Mexico.

Prey species consumed by the California sea lion include: Pacific herring; northern anchovy; plainfin midshipman, *Porichthys notatus;* Pacific hake; Pacific tomcod, *Microgadus proximus;* jacksmelt, *Atherinopsis californiensis;* white croaker, *Genyonemus lineatus;* rockfish, *Sebastes* sp.; rex sole, *Glyptocephalus zachirus;* slender sole; English sole, *Parophrys vetulus;* and squid, *Loligo opalescens* (Ainley et al., 1977; Best, 1963; Fiscus and Baines, 1966).

Sea lion spewings were examined at Southeast Farallon Island when sea lions were present throughout the year (Ainley et al., 1977). Investigators found that hake was an important food item, being found almost exclusively in the spewings when the population peaked on their southbound migration in April and May. Sea lion numbers during this peak period in 1974-75 were slightly under 1,400 animals and in 1976, slightly under 1,200.

In comparing the migratory movement and range of hake with that of the California sea lion, we can presume that the sea lion is not an important predator of hake from northern California north to British Columbia simply because so few (4,000, mostly adult males) range north of about the latitude of the Farallon Islands (lat. 38°N). Virtually the entire population of California sea lions are found south of lat. 34°N in the southern portion of the hake range during May-July. During the remainder of the year their movements are not so well understood with the exception of the 4,000 odd males that move north of lat. 38°N. California sea lions do not usually range far from land with the exception of solitary males. Surveys for the Bureau of Land Management (BLM) of the U.S. Department of Interior, indicate that sea lions rarely venture more than 50 km from their hauling grounds and are seldom seen outside the 500-fm (914.4-m) depth contour (Le Bouef et al., footnote 3). During the fall most adult males moved northward out of the California bight (lat. 32°-34°N) waters. Based on aerial transects, scientists conducting the BLM studies concluded that the ratio of animals at sea to those on land remains constant and that there are about one-third as many animals at sea as there are on land.

Northern Sea Lion

The range of the northern sea lion, *Eumetopias jubatus*, extends around the North Pacific rim — from southern California to the Bering Sea, to the Kurile Islands, and to the Okhotsk Sea. The southern limit of the northern sea lions' breeding range in the eastern North Pacific is located at San Miguel Island at about lat. 34°N. In 1977, the breeding population of San Miguel and adjacent Castle Rock was comprised of four adult females and two large males; three pups were born during the season. A census was not made at Richardson

[3]LeBoeuf, B. J., M. L. Bonnell, M. O. Pierson, D. H. Dettman, and B. D. Farrens. 1976. Pinnipedia: Numbers, distribution and movements in the Southern California Bight. Section I. *In* Regents of the University of California (editors), Marine mammal and seabird survey of the Southern California Bight area, p. III - 1-269. Draft final report 1975-1976, BLM contract 08550-CT5-28. Regents, Univ. Calif., Santa Cruz, Calif.

Rock near San Miguel but it usually has a population of 5-10 animals. The breeding colony at Ano Nuevo, at about lat. 37°N, in 1978 numbered about 1,200 animals (R. Gisiner, University of California, Santa Cruz, Calif., pers. commun.), a decline of about 33 percent from the population described in 1968-69 (Gentry, 1970). The breeding colony at Southeast Farallon Island, at about lat. 38°N, numbered less than 200 animals. Ainley et al. (1977) reported a breeding population of about 130 in 1976. The northern sea lion population on these three breeding areas has undergone a decline in numbers since the 1920's and 1930's as indicated in available census data. The northern sea lion population in California north of lat. 38°N in July contains about 800-900 animals; thus the California breeding season population numbers from 2,200 to 2,300 animals. A census made in July 1975 of sea lions in Oregon indicated a breeding season population of slightly over 2,000 (Mate, 1977). The Washington population (no rookeries) probably numbers less than 500 animals. The breeding population of northern sea lions in British Columbia is estimated to be about 5,000.

Northern sea lions are found in the central and northern portion of the hake habitat and number about 9,800 animals. The largest numbers (British Columbia) are found along the northern boundary of the hake range which is occupied by large numbers of hake only in the summer and early fall. There is apparently a general northward movement of northern sea lions after the breeding season similar to that which occurs in California sea lions.

Prey species consumed by the northern sea lion in this region include: Pacific lamprey, *Entosphenus tridentatus;* Pacific herring; salmon, *Oncorhynchus* sp.; Pacific hake; rockfish, *Sebastes* sp.; sanddab; turbot, *Pleuronichthys* sp.; squid; octopus; and other species of fishes and squids (Fiscus and Baines, 1966; Spalding, 1964).

Northern Fur Seal

The northern fur seal, *Callorhinus ursinus,* ranges across the subarctic waters of the North Pacific and numbers about 1.8 million. In that portion of the eastern North Pacific inhabited by the Pacific hake the fur seal is essentially absent from mid-June until late November (6 months) except for the San Miguel Island populations which number about 2,000 animals. Few adult males are found south of the Gulf of Alaska. Adult and subadult females and juvenile males and females begin to appear in coastal waters between British Columbia and central California in late November and early December, the pups slightly later in January-February. The movement is generally southward along the continental shelf and slope from January into March with some animals ranging south to about lat. 32°N; however, most of the wintering population can be found between about lat. 35° and 49°N. Some northward migration out of this region may begin as early as March and most of the wintering population has moved north of the hake range by mid-June.

Most wintering seals are found from over the continental shelf seaward as much as several hundred miles. They seldom approach land, although there are a few exceptions. During 1965-66 off California and in 1967 off Washington, transects were run from nearshore over the continental shelf and slope seaward over deep water; seals were seldom seen within 18-28 km of shore, being most numerous along the continental slope and those areas where bottom topography caused upwellings of nutrient rich water.

Fur seals are usually observed as single animals at sea, although pairs and groups of three are fairly common. The largest group seen in 15 years of ocean research numbered about 100 animals and was feeding in a large school of anchovies off the Farallon Islands, Calif. Fur seal densities are quite variable ranging from 0 to 20 per km^2. One day in March 1972, 169 seals were seen during a 12-hour cruise off Grays Harbor, Wash. During 12 other days of that month, the number of seals sighted ranged from 0 to 44.

Fur seals tend to congregate in areas of abundant food supply. They usually feed at night, probably because most prey species rise toward the surface after dark and are more readily available then.

The four most frequently identified prey species, according to percent of total stomach volumes in the sample and by frequency of occurrence, in stomachs of seals collected off California, Washington, and British Columbia are shown in Tables 2, 3, and 4, respectively. If a single hake appeared in the stomach contents, it is listed whether or not it was in the first four. Little sampling was done off Oregon and, as food items do not differ greatly from those found off northern California or Washington, Oregon data are not presented here. A brief summary of the presence and rank of hake in the stomachs of fur seals off California, Washington, and British Columbia is presented in Table 5.

In California waters in January and February (winter) hake was found in the stomachs of fur seals taken between lat. 33° and 36°N. Northern anchovy, squid, and saury form a major portion of the stomach contents at this time but hake did rank in the first four twice in four sampling periods. During the spring season, March through April, hake was found in samples taken between about lat. 36° and 41°N. These findings suggest that hake may be relatively unavailable in waters off central and northern California in winter but are present and available in spring and early summer.

In Washington and British Columbia waters, hake does not compose a significant part of the fur seal's diet in winter. Although hake is present in spring in the collections from these waters, only once was it among the first four in abundance. The entire northern fur seal population is estimated to be at least 1.8 million, and about 1.2 million may winter in the eastern North Pacific and the Bering Sea. The remaining 0.6 million winter in the western North Pacific, the Sea of Japan, and the Okhotsk Sea (National Marine Fisheries Service, 1976; Fiscus et al., 1977). The numbers of seals wintering in the range of Pacific hake will probably never be known; however, it seems reasonable to suggest that perhaps

500,000 fur seals utilize this area for approximately 3 months each year (January-March) and fewer than 500,000 for an additional 3 months (late November, December, April and May).

Saddleback Dolphin

In the eastern North Pacific, the saddleback dolphin, *Delphinus delphis,* is regularly found from about lat. 42°N south to lat. 10°N over the continental slope and for some distance offshore. Stragglers have been recorded as far north as British Columbia. Large populations occur from about lat. 32°N and southward along the west coast of Baja California. The total population is estimated to be 1.4 million; however, only an unknown portion of this species is found in the range of Pacific hake. This dolphin probably does not occur north of about lat. 38°N in sufficient numbers to have any appreciable effect on hake in the northern part of the hake range. In the California Bight, this species is the most numerous cetacean (Evans, 1976; Norris et al.[4]). Scientists conducting surveys for the BLM sighted approximately 34,000 animals including two schools whose size was estimated at over 8,000 animals in one school and from 6,000 to 7,000 animals in the second school. Prey species include: northern anchovy; Pacific hake; lanternfish, *Myctophidae* sp.; saury, *Cololabis saira;* and squids, *Gonatus* sp., *Onychoteuthis* sp., and *Loligo opalescens* (Fiscus and Niggol, 1965; Fitch and Brownell, 1968).

Pacific Whiteside Dolphin

The Pacific whiteside dolphin, *Lagenorhynchus obliquidens,* occurs in the eastern North Pacific from the Gulf of Alaska (in summer) south to Baja California. It occurs year round from Washington to California and is common in southern California inshore waters in winter and spring. Scientists conducting marine mammal surveys in the California Bight for BLM report that the mean herd size varied from 8 in one 3-month period to 167 in another, with a yearly mean of 90 (Norris et al., footnote 4).

Forty-five percent of the BLM sightings were in association with other cetaceans, (10 percent) pinnipeds, (7 percent) birds, or combination of these

Table 2.—Stomach contents of northern fur seals collected off California, 1958-66; the four most important prey species according to percent total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

			Principal prey species[1]		Principal prey species[1]		
Year	Season	No. of stomachs with food	Species	Percent of total volume	Species	Frequency of occurrence	Sampling area
1958	Winter (Feb.)	111	Saury	31.7	Squid-unident.	89	Central Calif. (Pt. Reyes to Pt. Sur)
			Squid-*Loligo*	26.2	Saury	40	
			Squid-unident.	10.6	Anchovy	18	
			Anchovy	10.0	Jack mackerel	16	
			Hake	2.8	Hake	4	
	Spring (Mar. Apr.)	212	Squid-unident.	24.6	Squid-unident.	174	Pt. Reyes to Pt. Conception
			Hake	22.0	Saury	62	
			Saury	16.7	Hake	52	
			Anchovy	15.9	Jack mackerel	28	
1959	Winter (Jan. Feb.)	617	Anchovy	73.7	Anchovy	436	Pt. Reyes to Pt. Conception
			Hake	22.0	Hake	207	
			Jacksmelt	1.7	Squid-unident	126	
			Saury	1.1	Saury	39	
	Spring (Mar. Apr.)	276	Hake	36.3	Squid-unident.	138	Pt. Sur to Crescent City
			Anchovy	16.3	Hake	111	
			Saury	10.2	Saury	65	
			Jack mackerel	9.2	Anchovy	40	
1961	Winter (Dec. Jan. Feb.)	490	Squid-*Onychoteuthis*	36.8	Squid-*Onychoteuthis*	262	Pt. Arena to Cortez Bank
			Anchovy	27.5	Squid-unident.	157	
			Saury	18.0	Saury	94	
			Squid-*Loligo*	7.5	Squid-Gonatidae	92	
			Hake	1.1	Hake	9	
	Spring (Mar. Apr.)	75	Anchovy	35.5	Anchovy	26	Pt. Arena to Monterey Bay
			Hake	22.6	Hake	18	
			Squid-*Loligo*	21.2	Squid-*Onychoteuthis*	18	
			Shad	3.4	Squid-*Loligo*	15	
1964	Spring (Apr. May)	228	Hake	73.8	Hake	129	Eureka to Pt. San Louis
			Squid-*Loligo*	12.9	Squid-*Loligo*	74	
			Squid-*Onychoteuthis*	2.4	Fish unident.	62	
			Anchovy	2.1	Squid-*Onychoteuthis*	27	
1965	Spring (Apr. May)	145	Hake	39.6	Squid-*Loligo*	60	Bodega Head to Pt. Sur
			Squid-*Loligo*	28.0	Hake	49	
			Rockfish[2]	12.2	Fish-unident.	41	
			Anchovy	11.7	Squid-*Onychoteuthis*	34	
	Summer (June)	81	Anchovy	29.7	Fish unident.	40	Bodega Head to Pt. Sur
			Hake	23.1	Squid-*Loligo*	25	
			Jack mackerel	14.6	Hake	21	
			Squid-*Loligo*	10.4	Squid-*Onychoteuthis*	15	
1966	Winter (Jan. Feb.)	187	Anchovy	85.2	Anchovy	123	Pt. Reyes to Cortez Bank
			Hake	7.9	Squid-*Loligo*	60	
			Saury	3.4	Squid-*Onychoteuthis*	45	
			Squid-*Onychoteuthis*	1.3	Fish unident.	42	
	Spring (Mar.)	144	Anchovy	55.6	Anchovy	57	Pt. Reyes to Cortez Bank
			Hake	40.8	Hake	47	
			Saury	1.7	Fish unident.	43	
			Magnisudus	1.1	Squid-*Onychoteuthis*	26	

[1]Hake included regardless of its rank among prey species.
[2]Mostly juvenile fish.

[4]Norris, K. S., T. P. Dohl, R. C. Guess, L. J. Hobbs, and M. W. Honig. 1976. Cetacea. Section II. *In* Regents of the University of California (editors), Marine mammal and seabird survey of the Southern California Bight area, p. III - 270-441. Draft final report 1975-1976, BLM contract 08550-CT5-28. Regents, Univ. Calif., Santa Cruz, Calif.

(19 percent). This species may be the most abundant dolphin off northern California, but no estimate of its population size off the west coast of North America has been made.

Prey species include: Pacific herring; northern anchovy; salmon; Pacific hake; saury; jack mackerel, *Trachurus symmetricus;* and the squids, *Loligo opalescens, Onychoteuthis borealijaponicus, Gonatopsis borealis, Abraliopsis* sp., *Gonatus* sp., and *Octopoteuthis* sp. (Fiscus and Niggol, 1965; Fitch and Brownell, 1968; Houck, 1961; Stroud et al.[5]).

Northern Right Whale Dolphin

In the eastern North Pacific, the northern right whale dolphin, *Lissodelphis borealis,* is found along the continental slope and seaward from about lat. 50°N south to about lat. 29°N, although this species is most frequently sighted between lat. 42° and 32°N. It is fairly abundant in California waters and is most frequently seen in pods of several hundred or more. Scientists working on BLM marine mammal surveys in the California Bight reported group sizes from 1 to 500 as follows: 5 sightings (20 percent), groups of 10 or less; 15 sightings (60 percent), groups of 10-100; and five sightings (20 percent), groups of more than 100 (Norris et al., footnote 4). This dolphin was reported in association with birds, pinnipeds, and other cetaceans (46 percent) or alone (64 percent). There are no population estimates available.

Prey species include: northern anchovy, Pacific hake, and squids (Fitch and Brownell, 1968).

Whitehead Grampus

The whitehead grampus, *Grampus griseus,* is found in the eastern North Pacific from British Columbia southward to southern California over the continental shelf and slope and seaward. This species is seen regularly but cannot be considered abundant in the area. It usually travels in small groups; however, one group of about 200 was seen off the Washington coast on 20 April 1972. No population estimates are available.

It is not known to prey on hake, but very few stomachs have been examined. The stomach from a grampus stranded on the Washington coast contained the squids *Onychoteuthis borealijaponicus, Octopoteuthis* sp., *Chiroteuthis veranyi,* and *Gonatus fabricii* and two other gonatid species (Stroud, 1968).

Shortfin Pilot Whale

In the eastern North Pacific the shortfin pilot whale, *Globicephala macrorhynchus,* occurs from southern Alaska to the tropics, but it probably does not occur north of about lat. 38°N

Table 3.—Stomach contents of northern fur seals collected off Washington by U.S. or Canadian research vessels 1958-68; the four most important prey species according to percent of total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

			Principal prey species[1]		Principal prey species[1]	
Year	Season	No. of stomachs with food	Species	Percent of total volume	Species	Frequency of occurrence
1958	Spring	50	Rockfish	51.2	Squid-unident.	30
	(Mar. Apr.)		Herring	17.3	Rockfish	15
			Saury	12.2	Saury	7
			Squid-unident.	11.0	Herring	7
1959	Spring	123	Rockfish	44.9	Squid-unident.	57
	(Mar. Apr.)		Sablefish	18.9	Rockfish	44
			Squid-unident.	9.5	Salmon	13
			Herring	7.2	Sablefish	12
			Hake	0.3	Hake	6
1960	Spring	124	Rockfish	48.0	Squid-unident.	46
	(Mar. Apr.)		Squid-unident.	24.6	Fish-unident.	36
			Herring	10.2	Rockfish	34
			Anchovy	7.5	Herring	16
1961	Spring	184	Anchovy	37.8	Anchovy	58
	(Mar. Apr.)		Rockfish	19.6	Herring	36
			Herring	17.4	Fish-unident.	35
			Shad	5.1	Rockfish	32
			Hake	0.3	Hake	2
1964	Spring	18	Hake	47.8	Smelt	9
	(Apr. May)		Smelt	18.0	Hake	4
			Rockfish	15.0	Anchovy	4
			Salmon	12.3	Squid-*Loligo*	3
1965	Spring	98	Anchovy	47.6	Fish-unident.	39
	(Apr.)		Smelt	17.7	Anchovy	21
			Salmon	11.3	Anchovy	20
			Herring	9.3	Smelt	11
1967	Winter	89	Herring	24.2	Squid-*Loligo*	47
	(Jan. Feb.)		Rockfish	17.6	Fish-unident.	20
			Shad	11.5	Herring	15
			Anchovy	11.0	Squid-Gonatidae	14
			Hake	0.3	Hake	2
	Spring	32	Salmon	45.4	Squid-	
	(Mar. Apr.		Rockfish	14.3	*Onychoteuthis*	9
	May)		Fish-unident.	10.2	Salmon	8
			Herring	6.0	Squid-	
			Hake	4.5	*Berryteuthis*	7
					Squid-unident.	7
					Hake	1
					Fish-unident.	82
1968	Winter	248	Salmon	22.7	Salmon	45
	(Dec. Jan.)		Anchovy	15.9	Squid-Gonatidae	39
			Rockfish	14.3	Anchovy	36
			Smelt	11.6	Hake	9
			Hake	3.3		

[1]Hake included regardless of its rank among prey species.

[5]Stroud, R. K., C. H. Fiscus, and H. Kajimura. 1979. Food of the Pacific whiteside dolphin *(Lagenorhynchus obliquidens),* Dall porpoise *(Phocoenoides dallii),* and northern fur seal *(Callorhinus ursinus)* off California and Washington. Unpubl. manuscr., 30 p. National Marine Mammal Laboratory, Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

in sufficient numbers to have any appreciable effect on hake in the northern part of the hake range. This species is found in the California Bight at all seasons but in larger numbers during winter. During the California Bight surveys, scientists found that 92 percent of the shortfin pilot whale sightings were of herds of less than 100 animals and in 22 percent of these sightings they were associated with other cetaceans, generally bottlenosed dolphins (Norris et al., footnote 4). No population estimate is available.

It is not known to prey on hake; however, it is capable of doing so. It probably feeds in spawning schools of the squid *Loligo opalescens* in the California Bight area where it has been observed.

Dall Porpoise

The Dall porpoise, *Phocoenoides dalli*, is found in the eastern North Pacific from the Bering Sea to the California Bight and into northern Baja California waters in winter. It is abundant throughout the range of Pacific hake except for that portion south of about lat. 34°N. Between lat. 34° and 32°N, it occurs in fall and winter with few sightings at other seasons. No population estimate is available.

Prey species include: Pacific herring; Pacific hake; saury; jack mackerel; and squids, *Loligo opalescens, Gonatus* sp., *Onychoteuthis borealijaponicus*, and *Abraliopsis* sp. (Norris and Prescott, 1961; Scheffer, 1953; Loeb, 1972; Best, 1963; Stroud et al., footnote 5; Cowan, 1944).

Hake Predators Other Than Marine Mammals

Any discussion of predation on hake should mention those predators, in addition to marine mammals, which also include hake in their diet. Almost any large fish or squid probably takes hake whenever encountered. A partial listing of fishes having hake in their stomachs upon capture includes: White shark, *Carcharodon carcharias;* soupfin shark, *Galeorhinus zyopterus;* Pacific electric ray, *Torpedo californica;* longnose lancetfish, *Alepisaurus ferox;* Pacific hake; Pacific bonito, *Sarda chiliensis;* albacore, *Thunnus alalunga;* bluefin tuna, *Thunnus thynnus;* rockfish; sablefish; lingcod, *Ophiodon elongatus;* bigmouth sole, *Hippoglossina stomata;* and arrowtooth flounder, *Atheresthes stomias* (Best, 1963; Nelson and Larkins, 1970; Pinkas et al., 1971).

This report does not cover all aspects of marine mammal-hake interrelationships, or present complete life histories of all species of marine mammals and fishes that prey upon or are preyed upon by hake. It does provide background information on the life history of hake, the commercial fishery, and information on most marine mammals that interact with hake.

Table 4.—Stomach contents of northern fur seals collected off British Columbia by Canadian research vessels, 1958-61; and four most important prey species according to percent of total stomach volumes and by frequency of occurrence in stomachs of all seals collected during the sampling period (North Pacific Fur Seal Commission, 1962, 1969, 1975).

			Principal prey species[1]		Principal prey species[1]	
Year	Season	No. of stomachs with food	Species	Percent of total volume	Species	Frequency of occurrence
1958	Spring (Mar.-Apr.)	251	Herring	78.9	Herring	124
			Sablefish	3.3	Squid-unident.	36
			Salmon	2.2	Sablefish	14
			Saury	2.2	Saury	13
			Hake	1.8	Hake	1
1959	Spring (Mar. Apr. May)	149	Herring	29.4	Herring	55
			Salmon	20.0	Squid-unident.	46
			Sablefish	16.2	Fish-unident.	44
			Rockfish	13.1	Sablefish	27
			Hake	0.1	Hake	2
1960	Spring (Mar. Apr. May)	136	Herring	34.9	Herring	54
			Sandlance	26.9	Fish-unident.	44
			Rockfish	14.9	Squid-unident.	24
			Salmon	6.9	Sandlance	21
			Hake	5.4	Hake	3
1961	Winter (Jan. Feb.)	61	Herring	88.7	Herring	30
			Sablefish	4.0	Fish-unident.	12
			Pacific cod	2.5	Squid-*Loligo*	7
			Squid-*Loligo*	1.2	Squid-unident.	6
	Spring (Mar. Apr. May)	225	Herring	36.5	Fish-unident.	62
			Salmon	12.1	Squid-unident.	56
			Stickleback	10.4	Herring	52
			Shad	8.9	Stickleback	19
			Hake	3.1	Hake	3

[1]Hake included regardless of its rank among prey species.

Table 5.—Summary of data in Tables 2, 3, and 4 on the occurrence of Pacific hake in stomachs of fur seals collected off the western U.S. coast, 1958.

State and season	No. of seasons sampled	Occurrence of hake (from Tables 2, 3, 4)	Occurrence of hake in collection
California			
Winter[1]	4	2	4
Spring[2]	6	6	6
Summer[3]	1	1	1
Washington			
Winter	2	0	2
Spring	7	1	4
British Columbia			
Winter	1	0	0
Spring	4	0	4

[1]Dec., Jan., Feb.
[2]Mar., Apr., May.
[3]June.

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Management for Increasing Clam Abundance

CLYDE L. MacKENZIE, Jr.

Introduction

Low abundance of the hard clam, *Mercenaria mercenaria,* and soft clam, *Mya arenaria,* in beds of the eastern United States has always had a strong limiting effect on local employment and incomes as well as market supplies of clams. Unlike agriculture, where progressive methods for increasing production have resulted in flourishing crops, the clam fishery is severely handicapped by a complete lack of practicable methods to increase clam abundance in beds through environmental improvement. The beds are wild and yield variable and limited clam quantities, and thus fishermen often have uncertain employment and critically low incomes. Because clam supplies to the market are limited, prices have constantly risen in recent years, with a tendency to price clams out of a broad-base market. The price of the hard clam has soared during the 1970's, producing a strong inflationary effect in the market. The situation, deleterious to the fishery and the market, could be rectified through increased clam abundance in beds. Thus, it is imperative that shellfish researchers and resource managers focus their attention on methods for increasing clam production.

Low clam abundance does not stem from a limited biotic potential of the clams. Indeed, only a minute fraction of the potential is realized as a clam yield to fishermen. The limitations on abundance are to be found in environmental constraints, such as predation, on the biotic potential. General awareness that clam abundance can be increased through environmental improvement has been absent. This paper presents background information on the clam fishery, data on biological and environmental factors that govern clam abundance, and suggestions for developing a strategy and tactics for increasing clam abundance.

Background

Clam Fishery Statistics

In 1977, the year of latest available data, commercial production of the hard clam in the eastern United States totalled about 1.2 million bushels (1 bushel =35.2 l), or 6,045 metric tons (t) of meat, with a landed value of slightly more than $25 million. Approximately 65 percent of the production was from New York, the remainder, in order of descending importance, was from Rhode Island, New Jersey, Virginia, North Carolina, Massachusetts, South Carolina, Maryland, and Maine.

In that same year, commercial production of the soft clam in the eastern United States totalled about 660,000 bushels, or 4,365 t of meat, with a landed value of about $12 million. Approximately 80 percent of the production was from Maine, the remainder was from Maryland, Massachusetts, New York, Rhode Island, and New Jersey (U.S. Department of Commerce, 1978a-i). In recent years, the demand for clams has far exceeded production, bringing increasingly higher prices. In 1977, clam prices reached an all-time high: Hard clams of the littleneck category (longest shell lengths, 5-5.7 cm =2-2.25 inches) brought fishermen more than $30 a bushel; soft clams brought fishermen from $15 to slightly more than $20 a bushel. Hard clams and soft clams within the length range 5-6.5 cm (2-2.6 inches) bring by far the highest demand and prices in the market. Clams are within that length range only about 2 years in most areas, then grow beyond it and have much less value. Ritchie (1977) reported that in 1975 nearly 17,000 part-time and full-time fishermen gathered the hard clam, and 7,000 part-time and full-time fishermen gathered the soft clam.

The Need for More Clams

The condition of uncertain and low clam abundance has consistently dominated the working atmosphere of the

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ABSTRACT–An urgent need exists to increase clam abundance in beds of the eastern United States in order to improve the economic status of clam fishermen and local communities as well as to increase clam supplies at stable market prices. Heretofore, clam fishermen have depended entirely on the vagaries of environmental factors to provide clams in beds, all of which are wild. The hard clam and soft clam each have a sufficiently large biotic potential to stock beds with clam populations of maximum abundance, but environmental factors suppress it, keeping clams in low abundance. In this paper, a strategy and tactics are suggested for increasing clam abundance by at least severalfold through improving environments of setting clam larvae, clam spat, and juveniles. The concept differs from conventional management based merely on gathering controls.

Figure 1.—Hard clams and trash gathered during a 5-minute raking by a fisherman through a bed in Great South Bay, New York, 1975. Small clam shells (the remnants of clams killed by predators), most seed clams, and predators had passed through the rake as it was being pulled. The fisherman gathered only about 1.5 bushels of clams (about 1,000 clams) during the day, showing that clam abundance was low. A fisherman commonly took 5 bushels of clams (3,500 clams) a day a few years earlier.

clam fishery (Fig. 1). The dependence by fishermen on clams gathered makes them hunger for stable supplies and increased abundance of clams. Fishermen fear that clam supplies will become depleted and thus are haunted by insecurity. Moreover, their earnings are usually slightly below that in most other occupations. On the other hand, clam fishermen are autonomous, independent, and somewhat self-sufficient. A scarcity of alternative work that features this freedom, and a lack of skills in other well-paying occupations, binds full-time clam fishermen to the beds. As a result, when clams become scarce, conditions of life become hard for fishermen. Clam fishermen desperately want increased employment security, at least modest prosperity, and the expectation of a good life for their children, all of which can be realized through increased clam abundance.

The clam fishery has always featured an irregular supply situation: Long periods of dearth may be followed by gluts. Consistently ample supplies would facilitate merchandising and stabilize prices.

Pollution has had detrimental effects on the clam fishery. The clam beds in polluted zones have been legally closed to gathering for direct public consumption, leaving fewer available clam beds (Ritchie, 1977). In some closed beds, clams are more abundant than in clean beds, an invitation to potential poachers. Increased clam supplies in clean beds would obviate that situation.

Coastal towns, counties, and rural areas where a clam fishery constitutes an important factor in their economies, view the fishery as a major supplier of jobs and income. They want the fishery to support as many people as possible in a stable, prosperous condition. Whenever clam supplies become scarce, total gainful employment and earned income drop, resulting in a weakened economy. A management program that supports a stable, prosperous clam fishery should be the aim of a community government. The minor problems and cost involved in establishing it would be far smaller than the problems and costs that stem from scarce clam supplies.

When any environmental factor that contributes to optimum conditions for clam survival begins to deteriorate uncontrollably, it is necessary to find means to remove other limiting factors to maintain or increase clam abundance. For example, deteriorating water quality could lead to reduced numbers of ready-to-set clam larvae, resulting in smaller populations. But this could be offset by an improved setting environment for larvae or an improved survival environment for spat and juvenile clams.

Clams support a sizable recreational fishery, especially in New England and Long Island, N.Y., where the hard clam grows in shallow water and the soft clam intertidally. The recreational clam fishery is a tourist attraction in some localities. Variable and low clam abundance makes the fishery uncertain.

Causes of Low Clam Abundance

The causes of low clam abundance (Table 1) are not hard to identify; they are: low setting densities of spat and predation on spat and juvenile clams (Fig. 2). Descriptions of the factors that

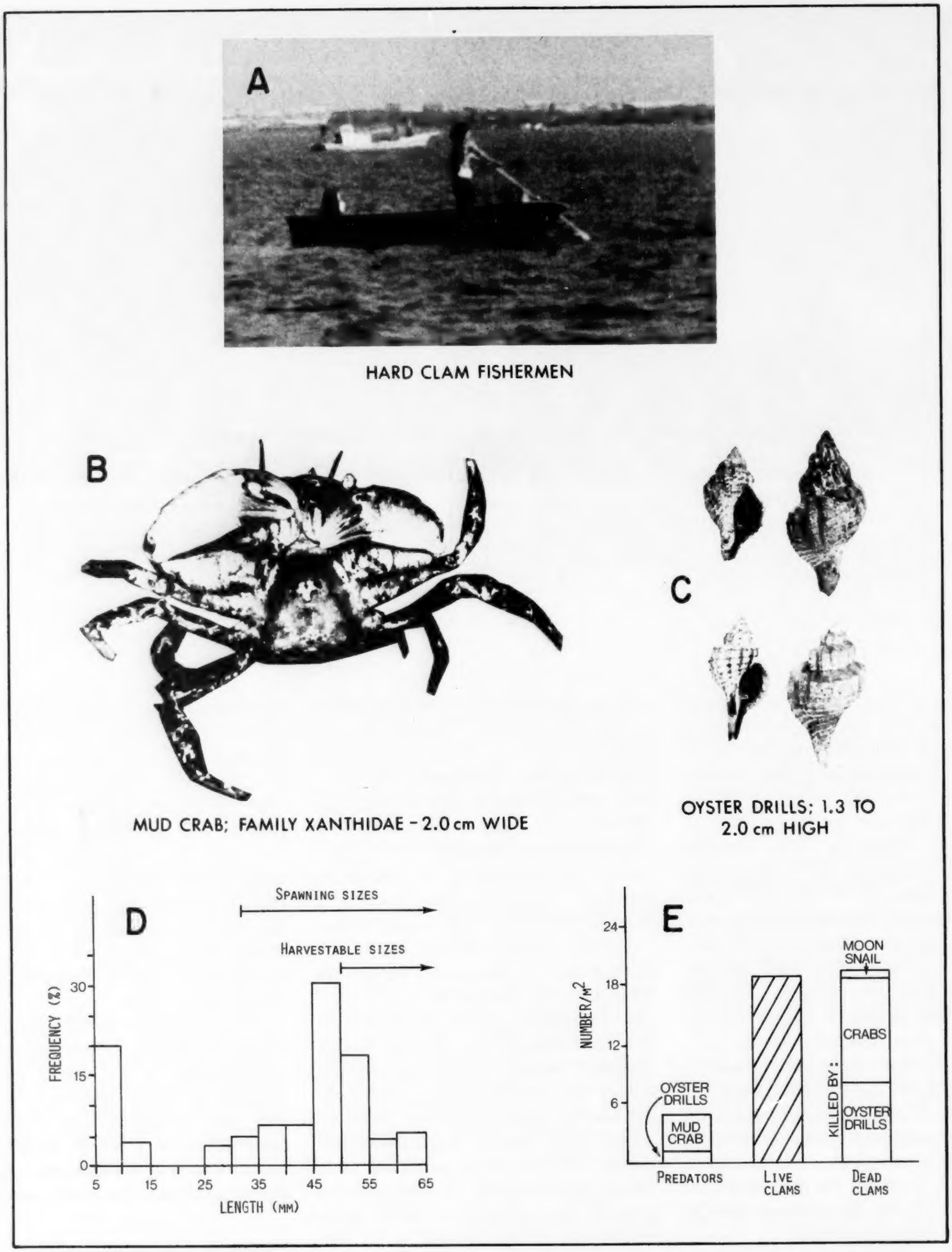

Figure 2.—Observations of the hard clam fishery in Great South Bay, Long Island, N.Y., in June 1975. Fisherman (A) takes the clams which, as larvae, were able to set in the bottom, avoided predators (B, C) and grew to and above the minimum legal gathering length, 5 cm (2 inches) or near equivalent, which is much longer than the smallest length at maturity, 3.2 cm, as shown in the length-frequency distribution of live clams in the Bay (D). Numbers of clam predators and live and dead clams are compared (E); dead clams ranged from 4.5 to 45 mm long. Mortality in clams was not measured in the length group from setting, about 0.2 mm, to 4.5 mm; mortality from predation in the group was probably substantial (MacKenzie, 1977a).

govern clam abundance are presented later in the paper.

Fishermen remove most legal-length clams (at least 5 cm, or near equivalent) from beds. Some clam populations can endure, however, under steady and heavy gathering by fishermen. A large number of clam beds along the Atlantic coast have yielded clams to fishermen for many years, some since the 1800's. Hard clam beds in Great South Bay, N.Y., and soft clam beds in Edgartown Great Pond, Mass., have yielded clams continuously to fishermen for at least the past 25 years. Whenever clam supplies have been reduced by fishermen to low densities, they returned when gathering was temporarily postponed and underlength clams grew to the minimum legal gathering length.

Some clam populations do not endure under gathering by fishermen. The populations are characterized by: 1) sparse and sporadic setting; 2) declining setting densities of spat; or 3) increasing predation on juvenile clams. Some clam populations grow gradually over an extended period and eventually are comprised mostly of relatively old clams, to be discovered and gathered by fishermen.

Belding (1930, 1931) reported large declines in hard clam and soft clam abundance in Massachusetts near the beginning of this century. At that time, the market demand was increasing, the number of fishermen increased correspondingly, and thus fewer clams in the regular beds were available to each fisherman. The fishermen discovered virgin hard clam populations in deeper water, which they gradually depleted. It is likely that the virgin populations had grown over a long period and were comprised mostly of old clams. Depletion occurred because the magnitude of subsequent spat setting was insufficient to overcome predation losses and support continuous gathering by fishermen. Belding (1930, 1931) attributed the reduced availability and depletion to "overfishing." The term "overfishing," however, implies that populations of spawning clams are reduced to such low density that reproduction is impaired. If clams below the minimum legal gathering length and some above it are left in the beds, spat setting density cannot be impaired by steady gathering by fishermen. Recruitment of legal length clams in a bed would be nearly the same whether or not gathering occurs.

Table 1.—Some recorded densities of the hard clam and soft clam, Atlantic coast of the United States.

Location	Density (number/m²)	Clam lengths (mm)	Data source
	Hard clam		
Connecticut			
Long Island Sound	0.9	5 to 10	MacKenzie, 1977a
New York			
Northport Bay	6.5	at least five year classes	MacKenzie, 1977a
Great South Bay	18.4	4.5 to 63	MacKenzie, 1977a
New Jersey			
Raritan Bay (Horseshoe Cove)	14.0	4.5 to 105	MacKenzie, 1977a
Lower Little Egg Harbor	34	5 to 84	Carriker, 1961
South Carolina			
Santee River	[1]18 to 24	not available	Rhodes et al., 1977
	Soft clam		
Maine			
Sagadahoc Bay	10.8 to 192.7	10 to 68	Spear, 1953
Massachusetts			
Boston Harbor	[2]320 to 3,200	a few year classes	Turner, 1952

[1]Approximate

[2]Approximate, includes beds with most dense clam populations.

Annual Setting Frequency of Clam Spat

The annual setting frequency of clam spat in beds has not received extensive study. The few existing reports and observations show that nearly every year clam setting takes place in some hard clam beds in New York (MacKenzie, 1977a) and New Jersey (Carriker, 1961; MacKenzie, 1977a), and in some soft clam beds in Maine (Glude, 1955; footnote 1), Massachusetts (pers. obs.), and Chesapeake Bay[2,3]. In other beds, clam setting takes place only when environmental conditions are exceptionally favorable, while in still others, setting rarely occurs (footnote 1; pers. obs). Probably, annual frequencies of clam setting are about the same in beds in other localities.

Clams set during the warm months. In Rhode Island, hard clam spat set from June through September (Landers, 1954a). In Maine, soft clam spat set mostly from June through September with the major portion of setting coming during 1 or 2 weeks out of the season (footnote 1); in Rhode Island, from May through October (Landers, 1954a); and in Chesapeake Bay, from March to November (footnote 2).

Three factors promote or favor regular clam setting in beds. The first is that an ample number of mature female clams is nearly always present in every bed. The number remains ample because each female releases millions of eggs a season (Table 2); thus, a few females can produce sufficient eggs to seed beds with large quantities of clam spat. Usually, large numbers of mature females occur in beds because: 1) Predators do not consume all spat and juvenile clams and cannot take clams above certain lengths; 2) fishermen retain only the hard clams and soft clams

[1]Letter dated 3 October 1978 from W. R. Welch, State of Maine, Fisheries Research Station, West Boothbay Harbor, Maine.

[2]Letter dated 3 October 1978 from H. T. Pfitzenmeyer, University of Maryland, Chesapeake Biological Laboratory, Solomons, Md.

[3]Letter dated 2 October 1978 from D. S. Haven, Virginia Institute of Marine Science, Gloucester Point, Va.

that have at least the minimum legal gathering length and leave in the beds below-length clams, many of which are mature (Fig. 3); and 3) after gathering clams, fishermen leave in the beds a quantity of legal length clams which are impractical to gather, yet capable of spawning. (The minimum legal length for clam retention has been in effect throughout nearly all the present century.)

The second factor is that the spawning season lasts a few months. During some part, if not all, of most seasons, environmental factors that stimulate mass spawning of clams and support some survival and setting of clam larvae exist.

The third factor is that fishermen do not degrade the clam environment while gathering clams; clams can set and grow in beds after, as well as before, gathering.

Figure 3.—Fishermen are required by regulation to return clams less than 5 cm (2 inches) long or near equivalent, termed seed, to the beds. The regulations help to ensure future adequate spawning capacity and yields of the clams from the beds. Shown here is the gathering of soft clams by hydraulic jet and rake on Martha's Vineyard, Mass. Clams are jetted from the bottom by one man, and are then raked up by his partner. Note the 2-inch measure for clams on the handle of clam rake.

Biological and Environmental Factors that Govern Clam Abundance

Biotic potential, environmental requirements, and environmental resistance are the factors that govern the abundance of clams reaching the legal gathering length. The factors are discussed later in this section.

Odum (1971) defines biotic potential as the maximum intrinsic capacity in a population to increase, and environmental resistance as the sum total of environmental limiting factors that prevent the biotic potential from being reached. Fluctuations in every aspect of clam productivity, i.e., number of eggs spawned, number of larvae that develop, spat density, and spat and juvenile survival and growth, are governed by environmental resistance; the number of clam spawners has less importance in governing the density of clam spat. Environmental resistance is the difference between the biotic potential and the actual clam quantities which grow in beds. The amount of environmental resistance to which clams are subjected varies constantly. When environmental resistance in a bed increases and endures, clam abundance becomes lower; when it decreases and endures, clam abundance becomes higher. Clam populations increase in relation to environmental resistance because the biotic potential of the clams is always much larger than reached in beds.

Table 2.—Data on biotic potential of the hard clam and soft clam, Atlantic coast of the United States.

Productivity	Hard clam	Data source	Soft clam	Data source
Smallest length at sexual maturity (cm)	3.2	Belding, 1931	1.3 to 1.9	Hanks, 1963
Eggs spawned per year (millions)	25	Davis and Chanley, 1956	[1]1 to 5	Stickney, 1964
Potential setting density of spat	unknown		unknown	
Actual setting density of spat (number/m²)	[2]up to 125	Carriker, 1961	more than 108,000	Turner, 1951
Annual growth increment (mm)	7 to 13	Belding, 1931	[3]8 to 35	Hanks, 1963
Physiological survival/year	very high	Haven and Andrews, 1956	unknown	
Physiological longevity	More than 25 years	Belding, 1931	More than 10 years	Belding, 1930

[1]Eggs released during a single spawning.
[2]Only a few determinations were made.
[3]Chesapeake Bay only.

The ecological principle of limiting factors, which is commonly used in agriculture, applies to clam populations. It can be explained as follows: if all environmental factors in beds remain optimum for clams, clam populations have maximum and sometimes in the soft clam, excess abundance; if any factor is less than optimum, populations will be reduced proportionately; and if any factor has a value of zero, even if all others remain optimum, the resulting populations will be small or nonexistent.

Early shellfish biologists did not study the causes and magnitudes of mortality in larvae and juvenile shellfish. They confined their investigations to adults. Nevertheless, mortality in clam larvae spat, and juveniles is large, many times larger than in adults. Recently, it has been shown that the magnitudes of setting density and predation on hard clams that are less than 1.5 to 2 cm long determine relative clam abundance, while predation on hard clams longer than 5 cm is neglible (MacKenzie, 1977a). Probably, the same is about true in the soft clam. Spat and juvenile clams suffer large mortality because a new generation of predators appears each summer simultaneously with each new generation of clams, both then being at peak abundance (Turner, 1953). The juvenile predators begin feeding immediately on spat and juvenile clams; moreover, adult predators select juvenile clams when mixed sizes are available. As they grow, the hard clams that survive become increasingly invulnerable to predation because the predators are not then sufficiently large to bore, crack, or swallow them (MacKenzie, 1977a). The largest soft clams may escape most predators by burrowing deeply.

Much remains to be learned about the factors that limit or constrain setting of clams and survival of spat and juvenile clams. Currently, little is known about: 1) The predators of clam larvae; and 2) the effect of associated biota growing on and among bottom sediments on setting density of the clam spat. Only speculative estimates have been made of typical setting densities of clam spat and the percentages of clams that survive from the spat stage to the minimum legal gathering length.

The available information on: 1) Biotic potential, 2) environmental requirements, and 3) environmental resistance of the hard clam and soft clam is summarized below.

Hard Clam

Biotic Potential

Table 2 lists information on the biotic potential of the hard clam. The clam can spawn at least 2 years before reaching the minimum legal gathering length (Fig. 2). Each adult female spawns millions of eggs a year, physiological survival is high, and spat grow to the minimum legal gathering length in 5-6 years. Clam larvae are dispersed in the water and while developing are carried about by currents; when fully developed, larvae set randomly in beds. The biotic potential is sufficiently large to stock beds with at least hundreds of clams over a wide length range per square meter within several years.

The hard clam sets in lower densities and grows more slowly than the soft clam, but the hard clam can live longer. Quantities of full-length empty hard clam shells, the remnants of dead clams, and live clams are about equal in beds, but more full-length soft clam shells than live soft clams occur in beds; the smaller shell quantity shows greater longevity in the hard clam. The contrast between shell quantities in beds of the hard clam and the eastern oyster, *Crassostrea virginica,* is striking. Usually, oyster beds contain oyster shell deposits which are several meters deep; the beds contain a great many more shells than live oysters. The difference in shell quantities shows that the hard clam lives much longer than the oyster, which commonly lives a few years.

Environmental Requirements

The hard clam is adapted to salinities from about 15‰ (Chanley, 1957; Andrews, 1970; Castagna and Chanley, 1973) to 35‰ (Belding, 1931; Davis, 1958), and normally grows in sand, sand-gravel-stone, and mud, at depths from about the low tide mark to at least 7 m. In summer, temperatures must rise above 15°C for spawning, but remain below 33°C for effective larval development (Loosanoff et al., 1951). Larvae seem to prefer bottoms of sand and a mixture of sand and mud which contain sufficient loose material to permit them to burrow as spat (Carriker, 1961). For some clam seed to survive, a bed must have few predators, or some protective cover, such as stones and eelgrass, *Zostera marina;* clams are most numerous in beds in which predators are scarce or cover from predators is available (MacKenzie, 1977a).

Environmental Resistance

The temperature and salinity extremes that suppress growth of hard clam larvae have been determined. Larvae grew slowly at and below 17.5°C and at 32.5°C, and at and below 17.5‰; growth was fastest at 20.0° to 30.0°C and 20.0 to 27.0‰, in laboratory cultures (Davis and Calabrese, 1964).

Some sediment types suppress setting and growth of the hard clam. Bottoms of mud (Carriker, 1961; Keck et al., 1974), coarse gravel, or shell (Carriker, 1961) are less desirable for clam setting and consequently contain fewer clams than sand. Growth is relatively slow in sediments that contain quantities of silt-clay (Pratt and Campbell, 1956).

The predators of hard clam larvae have not been identified. Nevertheless, it has been suggested that one or more bottom-dwelling invertebrate species may consume the larvae (Carriker, 1961). The known predators of burrowed hard clams over the entire range of the clam include: Moon snail, *Polinices duplicatus* (Mead and Barnes, 1904; Belding, 1931; Carriker, 1951, 1961; MacKenzie, 1977a); oyster drills, *Urosalpinx cinerea, Eupleura caudata* (Carriker, 1951, 1955, 1957, 1961; MacKenzie, 1977a); whelks, *Busycon canaliculatum, Busycon carica* (Belding, 1931; Carriker, 1951; MacKenzie, 1977a); blue crab, *Callinectes sapidus* (Carriker, 1951, 1956, 1959, 1961; Castagna and Kraeuter, 1977; MacKenzie, 1977a); green

crab, *Carcinus maenas* (Dow and Wallace, 1952; Carriker, 1956, 1961); rock crab, *Cancer irroratus* (MacKenzie, 1977a); mud crabs (Xanthidae) (Landers, 1954b; Carriker, 1956, 1959, 1961; MacKenzie, 1977a); starfish, *Asterias forbesi* (Belding, 1931; Pratt and Campbell, 1956); various rays (Dasyatidae, Myliobatidae, and Rhinopteridae) (Castagna and Kraeuter, 1977); summer flounder, *Paralichthys dentatus;* tautog, *Tautoga onitis;* and puffer, *Sphaeroides maculatus* (MacKenzie, 1977a). The total assemblage of predators never inhabits any one bay or bed.

Various field studies have shown that predation substantially reduces hard clam abundance (Landers, 1954b; Carriker, 1956, 1959, 1961; Castagna and Kraeuter, 1977; MacKenzie, 1977a). Wherever they are numerous, predators eliminate quantities of, and sometimes most, spat and juvenile clams—far more clams than fishermen gather—before the clams reach 5 cm in virtually all beds. The magnitude of predation was partially illustrated in two test areas in New York where clams became seven and eight times as dense (43.6 clams as compared with 6.5 clams/m^2, and to 75 clams as compared with 9.5 clams/m^2) after predator numbers were greatly reduced by a single application of poison as in unpoisoned areas nearby (MacKenzie, 1977a).

Soft Clam

Biotic Potential

Table 2 lists information on the biotic potential of the soft clam. The clam can spawn at least a year before attaining the minimum legal gathering length. Each adult female spawns millions of eggs per year, physiological survival is probably high, and spat grow to the minimum legal gathering length in 2-6 years, depending on latitude. Clam larvae are dispersed in the water and while developing are carried about by currents; when fully developed, larvae set randomly in beds. The biotic potential is sufficiently large to stock beds with at least a few thousand clams over a wide length range per square meter within a few years.

Environmental Requirements

The soft clam is adapted to salinities from about 2.5‰ (Chanley, 1957; Pfitzenmeyer and Drobeck, 1963; Castagna and Chanley, 1973) to 35‰ (Castagna and Chanley, 1973); its larvae grow in salinities as high as 32‰ (the highest point tested) (Stickney, 1964). The clam grows in intertidal flats and to depths of at least a few meters. Fine sand, mud, and pebbly sand are suitable sediments (Turner, 1950). In summer, temperatures must rise to nearly 10°C for spawning, but not greatly exceed 24°C or else the larvae will not develop (Stickney, 1964). A bed must have few predators for some clam seed to survive.

Environmental Resistance

The temperature and low salinity extremes that suppress the biotic potential of the soft clam have been determined. Clam larvae grew little at 8.6°C, but grew at 14.6°C, the next higher temperature tested; larvae were killed at 28.4°C within 14 days, but grew at 22.9°C, the next lower temperature tested, in laboratory cultures (Stickney, 1964). Burrowed clams were killed when temperatures persisted in the high 20°C range and salinities were 2‰ or lower in Maryland (Shaw and Hamons, 1974).

The bay anemone, *Diadumene leucolena,* has been tentatively identified as a predator of soft clam larvae in Chesapeake Bay (MacKenzie, 1977b). The bay anemone is abundant in polluted estuaries of northern New Jersey, which contains soft clam beds, and Delaware Bay; its distribution along the remainder of the western Atlantic coast is incompletely known.

The known predators of burrowed soft clams over the entire range of the clam, include: Moon snail (Belding, 1930; Turner, 1948, 1949, 1950, 1951; Turner et al., 1948a; Sawyer, 1950; Hanks, 1952; Smith and Chin, 1953; Medcof and Thurber, 1959; Edwards and Huebner, 1977); lady crab *Ovalipes ocellatus* (Belding, 1930; Turner, 1948); blue crab (Belding, 1930; Turner, 1948, 1950; Turner et al. 1948b); green crab (Turner et al., 1948b; Turner, 1950, 1951; Smith and Chin, 1953; Glude, 1955; Smith et al., 1955; MacPhail et al., 1955; Ropes, 1968); spider crab, *Libinia* sp. (Turner, 1950, 1951); horseshoe "crab," *Limulus polyphemus* (Belding, 1930; Turner, 1948, 1949, 1950, 1951; Turner et al., 1948a; Shuster, 1950; Smith and Chin, 1953; Smith et al., 1955; Carriker, 1961); starfish (Belding, 1930; Turner, 1948); eel, *Anguilla rostrata* (Wenner and Musick, 1975); winter flounder, *Pseudopleuronectes americanus* (Medcof and MacPhail, 1952); and ducks (Belding, 1930). The total assemblage of predators never inhabits any one bay, river, or bed.

Field studies have shown that predation substantially reduces soft clam abundance (Turner, 1948, 1950; Turner et al., 1948a, 1948b; Dow and Wallace, 1952; Smith and Chin, 1953; Glude, 1955; MacPhail et al., 1955; Smith et al., 1955; Medcof and Thurber, 1959; Hanks, 1963; Edwards and Huebner, 1977), comparable with its effect on hard clam abundance. Probably, the green crab is the most destructive soft clam predator north of Cape Cod, taking most clams in commercial beds when it is abundant (Glude, 1955; Hanks, 1963). During the 1940's, soft clam production declined sharply and became low, and through the mid-1950's, it remained low, in Maine and Massachusetts. The decline was caused by a sharp increase in numbers of the green crab, which destroyed virtually all seed clams (Glude, 1955). During the late 1950's, clam production rose again and remained sizable, at least through the late 1960's, because the green crab became scarce (Welch, 1968). The magnitude of predation on the soft clam in Maine and Massachusetts was further illustrated when the green crab and other predators were excluded with fences in clam beds. Clam densities became many times higher inside than outside the fenced areas during a summer (Turner, 1950; Smith and Chin, 1953; Glude, 1955; Smith et al., 1955; Hanks, 1963).

Some additional types of environmental resistance are present in hard clam and soft clam beds. The circula-

tion between bays and the ocean, weather and climatic factors, currents, and pollution also affect clam abundance.

Management Objective

The management objective of clam beds should be to increase the abundance of clams that reach the minimum legal gathering length (5 cm, or near equivalent).

Developing a Strategy and Tactics for Increasing Clam Abundance

The Basis for Increasing Clam Abundance

Management for increasing clam abundance is based on the fact that clams become more abundant after their environments improve. The avenue to increased abundance is through providing an improved environment for each clam so its setting and survival efficiency can be increased.

Usually, only one or two major abundance-limiting factors exist in commercial clam beds, besides temperature and, in some areas, salinity extremes. If a major limiting factor of clam setting were removed, and a major limiting factor of clam survival in the spat or juvenile stage were also removed through predator reduction, clam populations would irrupt. Furthermore, if the factors were removed every year, thereby improving the clam environment permanently, the beds would then consistently carry clam populations of maximum abundance.[4] Predator reduction, by itself, might produce almost the same result. Adjustments in temperature and probably salinity to accommodate the environmental requirements of clams are impracticable in all beds.

[4]The carrying capacity of clam beds is probably somewhere between 100 and 250 clams, that have a full range of sizes, per square meter; an excess number would need to be transplanted to other beds to allow adequate clam growth. Probably, hard clam beds can carry fewer clams than soft clam beds.

Information Needed From Each Clam Bed

In developing methods to increase clam abundance in beds, the setting regularity of the clam would need to be determined and the factors that limit or constrain clam setting and survival, identified. Only the limiting factors that can be practicably removed need to be identified; thus, studies on effects such as temperature and salinity extremes need not be made.

An estimate of setting regularity can be made from examination of the length distribution of clams. Clams can be sampled from the beds for measuring by using a hydraulic suction sampler with a fine-mesh bag and operated by a scuba diver (Brett, 1964). All existing clam lengths in proportion to their numbers that exist in the beds need to be included. For the hard clam, length groupings of about 10 mm intervals, approximating annual growth increments, are marked off and the number of clams in each is listed. If some clams appear in all groupings, it shows that setting has occurred every year; if gaps exist, setting has occurred irregularly. (Figure 2D shows a gap between 15 and 25 mm; thus, clams did not set in the year represented by the gap, but they did set in the remaining years that were represented.) For the soft clam, appropriately wider length groupings would be used.

The factors that limit setting and survival can be identified and assessed by: 1) Making scuba examinations of the beds; and 2) taking bottom samples for later examination with a hydraulic suction sampler with a fine-mesh bag to collect predators. Soft clam beds should be examined and sampled at high tide. Answers to the following questions will provide the information needed to evaluate bottom conditions for setting of clam larvae and survival of clam spat and juveniles. The questions concerning the bottom condition for setting are as follows:

1) Are predators of larvae present, and if so, in what densities, and will they kill a substantial percentage of larvae?

2) Do grain sizes of surface sediments inhibit setting of larvae, and if so, by about how much?

3) Do biota in surface sediments inhibit setting of larvae, and if so, by about how much?

The questions concerning the bottom condition for survival are as follows:

1) What predator species of clam spat and juveniles are present, during and immediately following the setting period of the spat?

2) What is the density of each predator species, by juvenile and adult? As an estimate, will the assemblage of predators in the numbers present kill a substantial percentage of clams, and if so, about what percentages in defined periods of time?

The following questions concerning management of the beds should be answered:

1) Is it feasible to remove the abundance-limiting environmental factors?

2) What are the costs and benefits of an action such as a reduction in predator numbers?

Resources are then concentrated wherever the chances of increasing clam abundance seem best. Ideally, when a major limiting factor is removed, with little expense or effort, at least a severalfold increase in clam abundance will follow. The methods for removing the limiting factors should be conceived, constructed, and applied with surgical precision.

Possibilities of Increasing Setting Densities

Undoubtedly, predation of soft clam larvae by the bay anemone, which has an unprotected, delicate body, could be greatly reduced by controlling the anemone with a light application of granulated quicklime (CaO). The correct grain size of quicklime has to be used: A screen of 10 meshes/25 mm^2 should retain only a trace of quicklime; and one of 100 meshes/25 mm^2 should retain 98 percent of quicklime. The anemones should be controlled immediately before the setting of clam spat.

Future studies can be made to diagnose and prescribe remedial action to

remove other constraints on setting densities of the hard clam and soft clam. It may be possible to increase setting densities by: 1) Removing a shell cover from the bottom; 2) hydraulically jetting the bottom to improve grain sizes; and 3) spreading quicklime to reduce the quantities of biota in sediments.

A major opportunity to increase clam abundance is through controlling predators of clam spat and juveniles.

Predator Reduction Possibilities

The prospects of predator reduction are excellent because most predators, juveniles and adults, remain on the bottom surface, at least during the warmer months, often by day and nearly always by night. On the other hand, the clams are embedded: The hard clam is shallowly burrowed, but has a relatively high specific density; the soft clam is deeply burrowed. It should be possible to remove predators from the bottom without disturbing the clams. Most clam beds have surfaces of sand with only small quantities of shells and stones, which means that shells and stones will not interfere with predator removal.

The frequency of predator removal would depend on whether or not the beds were subjected to recurrent predator invasions. In beds that are not especially subjected to predator invasions, removal of most juvenile and adult predators once or twice during or immediately following the setting period of the clam spat should lead to a severalfold increase in clam abundance. Clams are then at peak abundance, and mortalities of clam spat from predation are substantial. Some predators, such as the oyster drills and mud crab, migrate little, and therefore reinvasions by the two predators would be negligible. In some areas, the blue crab, rock crab, green crab, or horseshoe "crab" may randomly enter beds and destroy many clams. The green crab migrates onto intertidal soft clam beds at high tide and off at low tide, always remaining on the bottom surface (Dexter, 1947; Edwards, 1958), and feeding mostly by night (Naylor, 1958). Crab invasions could be controlled with methods suggested here.

During the late 1940's and 1950's, experiments using low wire fences to exclude predators were conducted in soft clam beds in Maine (Glude, 1955; Hanks, 1963) and Massachusetts (Turner, 1950; Smith and Chin, 1953; Smith et al., 1955). As stated above, the fences excluded most predators and clam densities became many times higher inside than outside the fenced areas; the fences were impracticable to maintain, however, and were not a commercial success. During the early 1960's, a chemical method was tested to control the green crab: Pieces of fish soaked in poison were supported on lines strung across the mouths of creeks, coves, and bays. Crabs entering the areas fed on the fish and died before reaching the clams (Hanks, 1961, 1963). However, the poisoned fish lines also were not a commercial success.

Mechanical methods need to be developed for removing predators from clam beds.

Developing Mechanical Methods for Predator Removal

The methods should remove juvenile and adult predators, and should do so without damaging or removing clams, or otherwise disturbing the bottom. The methods should be simple, inexpensive, and capable of removing predators from extensive areas within a short time; anything which adds to the complexity and expense of the methods should be avoided.

Some predators, such as crabs and the starfish, have relatively low specific density and can be easily lifted from the bottom by a slight water current which will not disturb clams. A board-net array which consists of a pressure board towed over the bottom followed by a net could remove predators that have low specific density. Using scuba, we have observed that the turbulence created behind a wooden board, held in a bridle and towed at a 45° angle over the bottom, lifts crabs and starfish off the bottom. The board was 4.25 m (14 feet) long, 30.5 cm (12 inches) wide, and 5 cm (2 inches) thick. A fine-mesh net towed behind the board might then catch the suspended predators (Fig. 4). Most small clams which were lifted from the sediments by the board would likely pass through the net. The net would have to be retrieved periodically for emptying. The board-net might also remove some predators that have high specific density such as the oyster drills and moon snail; trials would have to be conducted when the moon snail was on the surface. Before the board-net could be used, the bottom would have to be cleaned of loose algae, such as sea lettuce, *Ulva lactuca,* and any shells which would plug the net. A wide dredge could be used for such prior cleaning.

A more elaborate possibility is a collector having two tandem components. The first would lift the predators by directing a water current at the bottom and the second would catch them above the bottom on a screen. The predators could be brought to the surface by suction hose for disposal.

The moon snail which surfaces in larger numbers by night than by day (Medcof and Thurber, 1959) could be removed by night with a wide surface dredge or skimmer having a sufficiently fine screen bag to hold the snails.

In some clam beds, oyster drill abundance appears to be limited by the availability of surface shells to which the drills attach their egg cases when spawning. The beds, e.g., those in Great South Bay, N.Y., have scattered, mostly small, shells on their surfaces. Probably, shell removal would lead to a reduction of oyster drill abundance. The predator board-net could be used for removing the shells.

Any biological researchers and resource managers who decide to specialize in clam production should be able to develop effective tactics for removing predators from clam beds within a few months. The clam production specialists should have imagination, mechanical ability, a feel for working with nature, and probably have the capability to use scuba. They would need a vessel, testing equipment, and testing beds, besides the

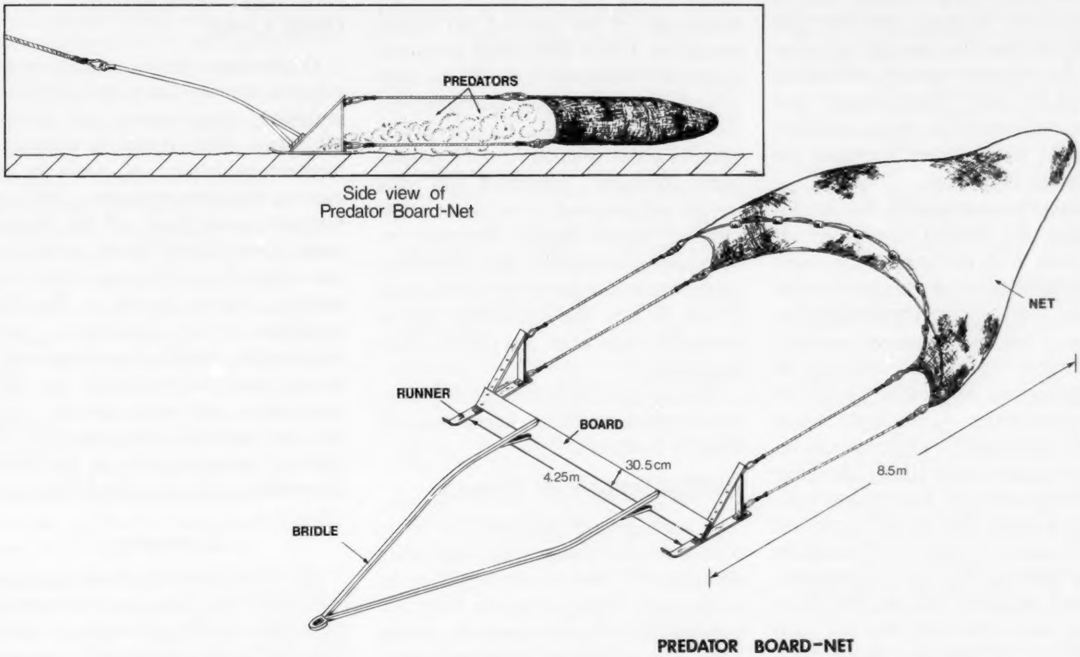

Figure 4.—Conceptual model of a board-net which could be tried for removing predators from clam beds. Adjustments in board distance from the bottom, distance between board and net, size of floats and weights on net, mesh size, and towing speed, and possible addition of small doors on net, could be made while testing the board-net to remove predators, but not remove the clams. Inset shows side view of board-net being towed and how predators might be lifted by board and enter net. A board-net of this width has the potential to remove predators from a few hectares (several acres) of bottom in an 8-hour day. In 1979, the cost of its construction would be about $600; $300 for the board and supporting structures, and $300 for the net.

necessary time. Development of predator-removal methods will involve trial and error testing, by night as well as by day, followed by sampling of predator and clam densities. After the predators have been removed from the beds, clam densities would be compared periodically with those in control beds. A hydraulic suction sampler with a fine-mesh bag and operated by a scuba diver can be used to measure the densities. Eventually, documentation of costs and benefits of using the methods would be needed. As a precaution against damage to commercial beds, methods should be tested, perfected, and proven effective on small areas.

Side Effects of Predator Reduction

Predator reduction on clam beds would not impinge on other interests. The ingredients of quicklime are natural components of bay and estuarine water and shells, and also flow into the water from farmland treated with lime. A light bottom application of spread quicklime dissolves in 2-3 days. The mechanical methods for removing predators would be used for only brief periods, and thus would not interfere with navigation. Predator numbers would become greatly reduced, thereby shifting typical numerical ratios of predator to prey in wild beds; the new ratio would be similar to one that occasionally occurs in beds when predators become scarce from natural causes and where afterwards clam populations irrupt. Predator reduction in clam beds would be followed by large increases in numbers of polychaetes, other mollusks, and other invertebrates, along with the clams. Predator and invertebrate numbers would not be affected in areas other than the clam beds.

Incorporating Methods Into Practice

It will do little good to develop effective methods for removing predators from clam beds unless they are put into practice. The development process will not be complete until the new methods result in increased abundances, yields, employment, incomes, and supplies. Any effective method to be successfully put into practice must qualify as follows: 1) Meet an urgent need; 2) be technically and operationally feasible; 3) offer no damaging risks to the beds; 4) will not impinge on other interests; and 5) will yield a return that exceeds the investment which, primarily, should be low. Probably, with clams, a method would have to produce at least a twofold increase in clam abundance at

an annual cost within the range of about \$75-\$125 per hectare (\$30-\$50 per acre) to be attractive enough to implement. An effective method, which has been conceived, constructed, and applied with precision, would undoubtedly yield much larger increases for roughly the same cost.

It should be recognized that implementation of a method on commercial clam beds will be one of the most difficult hurdles in the translation of an idea into more clams. Implementation is difficult because it means impingement directly upon the livelihoods of clam fishermen and other people in local communities. Accordingly, when the time gets close to implementation, an uncertainty will likely develop within fishermen and local people concerning whether the use of a method will be beneficial; they will not want to risk the little security and the employment and incomes that the fishermen already have. The fact that no such method has ever been used on any clam bed will amplify the uncertainty.

Naturally, clam production specialists would be at first eager to implement their method, especially if they have been deeply committed to its development. However, they may come to fear that negative reaction will arise among the fishermen and local people, which could lead to criticism of their work, damage to their reputations, and permanent loss of their credibilities. If it happens, specialists should not leave the development process at this point. Specialists make a mistake by leaving a designed and developed system before it has been properly implemented, because subsequent implementation by others than the developers is rarely successful.

The decision about whether to implement a method lies with the fishermen and local people because they have community responsibility over the beds. Accordingly, the specialists must thoroughly demonstrate the method on the testing beds and supply convincing evidence of its effectiveness by showing them samples of higher abundance of juvenile clams. The fishermen and local people should have ample opportunity to examine all features and performances of the method; all angles should be freely discussed, criticisms aired, or alternative methods suggested. Then, after such deliberations, the specialists should sample public opinion about whether or not to implement. Probably, fishermen and local people will respond favorably to a new method which clearly promises increased production and monetary gains, and will urge the specialists to go ahead. If not, the specialists should consider whatever revisions were suggested.

During the implementation phase, personnel who will use the method will have to be trained.

Political Support for Program

A management program, of whatever size, for maintaining high clam abundance in beds would be under the sponsorship of the governing body of a community. Such a program would have to be established by the respective civic authority which is fiscally empowered to undertake such a project. It would entail the will, determination, and commitment of those involved, who are entrusted to make such decisions. The production specialist would have to meet with the civic body to explain the designed process for increasing clam yields, and submit evidence of its potential effectiveness. Computed evidence of tangible increases in yields, concomitantly increased employment and incomes, will be highly influential in winning support for, and later maintaining, the program.

Clam Production Specialists Guide Program

After the establishment of a management program to increase clam abundance in a locality, it is advisable for production specialists to consult, at least 1 or 2 days a year, with operating personnel on the beds. Such consultations would include an examination of the beds and pertinent discussions to keep the program on track and improve efficiency. A program may gradually fail to function if not stimulated by such consulting.

Increasing Abundance of Ocean Clams

Ocean clams inhabit an environment which is probably far from optimum for maximum clam setting and survival efficiency. Thus, it may be possible to increase abundance of clams by improving their environments. The commercial ocean clams off the Atlantic coast of the United States are the surf clam, *Spisula solidissima*, and ocean quahog, *Arctica islandica*. The clam predators include gastropods, crabs, and starfish. Application of methods to remove any major factors that limit clam setting and reduce predator numbers to improve clam environments may not be practicable in the ocean. Nevertheless, the idea should be tested.

Conclusion

The objective of clam management, to increase clam abundance in beds and consequent yields and supplies, can be achieved when practicable, low-cost methods are developed and used for removing predators from clam beds. The examples from test areas in wild clam beds of substantial increases in abundance of the hard clam and soft clam following poisoning and fencing-out, respectively, of predators show that clam abundance will also increase substantially after predators are removed from other wild clam beds. Studies should be undertaken to determine whether or not setting densities of clam spat can be increased with practicable methods. A permanent increase in clam abundance and yields will vitalize the clam fishery and thus meet basic human needs by: 1) Increasing the economic security, stability, and prosperity of clam fishermen; 2) stimulating the economy of local communities; and 3) increasing clam supplies at more stable prices in the market, without substantial cost in money or time.

Heretofore, clam management has been designed to conserve clam populations and ensure continuous clam yields. As stated above, various state and local regulations restrict the clam sizes and quantities to be gathered and the types of gathering gear. The con-

servation management concept somewhat parallels management of many of the wildlife resources, such as freshwater fish, waterfowl, and upland game of our nation. It differs in that attempts have been made to increase wildlife abundance within the three categories through environmental improvement. The management goals have been successfully reached through the legal restrictions on clam gathering, but under the conservation concept, clams can and do become scarce for years. No attitudes and solutions within the concept exist to increase clam abundance. Imposing increased restrictions on gathering clams will never create increased clam abundance. This has been evidenced when freshwater fish, waterfowl, and upland game did not increase with the imposition of increased restrictions on fishing and hunting.

Conventional management for the conservation of clam populations should be replaced with a management concept which embraces conservation and increased clam abundance through environmental improvement. Permanent increases in clam abundance can be brought about through a combination of: 1) a continuation of the regulations prohibiting the gathering of small clams; 2) problem-oriented research and development, and implementation of methods and programs for improving clam environments by clam production specialists; 3) establishment of the programs by decision-making civic bodies, authorized and willing to do it; and 4) guidance by the production specialists in the years after programs have been established.

Removing the constraints on clam abundance in beds, which have heretofore consistently deprived clam fishermen, local communities, and the market, will benefit everyone.

Acknowledgments

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The Japanese Longline Fishery in the Gulf of Mexico, 1978

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Introduction

The Fishery Conservation and Management Act of 1976 (FCMA), Public Law 94-265, provides for the conservation and management of fishery resources of the United States by establishing a fishery conservation zone (FCZ) of 200 nautical miles. This law allows the United States to manage all marine resources within these waters with the exception of highly migratory fishes, such as the tunas.

Since the United States has an interest in billfishes and sharks as a recreational fishery, formal management plans have been developed for such species. Under the authority of the FCMA, a preliminary management plan (PMP) for Atlantic billfishes and sharks was prepared by the National Marine Fisheries Service and implemented on 20 March 1978. Basically, the PMP requires that all foreign vessels fishing within the FCZ obtain a permit, maintain logs recording amount and location of catch, release all billfishes and sharks whether dead or alive, and allow boarding and observation of fishing activities by U.S. observers.

The first boarding was conducted on 28 February 1978, aboard the Japanese vessel *Masa Maru #28* in the northern Gulf of Mexico. For the 1978 fishing season in the Gulf of Mexico, 21 boardings were made and 167 fishing days monitored. All boardings were on Japanese longliners fishing in the northern Gulf of Mexico for bluefin and yellowfin tuna (Fig. 1). Observers were responsible for recording the amount and identifying the species of fish caught. They were also responsible for determining whether the fish were dead or alive when brought alongside, with emphasis being on billfishes, for tagging and releasing all live billfish, and for collecting biological samples from tunas with the permission and cooperation of the Japanese.

This paper describes the general fishing operation of Japanese longline vessels, and provides information on the incidental catch of all species including billfishes and sharks.

Vessel Description

The typical Japanese longline fishing vessel operating in the Gulf of Mexico ranges from 50 to 70 m in length and is well equipped with radio and navigational equipment (Fig. 2). Hold capacity ranges from 300 to 500 metric tons (t) of frozen fish and the vessels usually stay at sea until the fish holds are filled. This normally takes from 9 to 10 months depending on fishing success. Freezing facilities consist of a cooling room, a flash freezing room, and three or more storage freezers, with temperatures of approximately -20°, -70°, and -50°C, respectively. The number of crew members is generally 21-25 and only 2 or 3 do not actively participate in fishing operations.

The longline is set from the stern of the vessel and haulback and fish processing takes place on the forward quarterdeck. Conveyor belts are used to transport fishing gear between these areas.

Fishing Gear Description

The longline used by Japanese tuna vessels in the Gulf of Mexico consists of a main line suspended horizontally from the surface by floats and a series of branch lines (gangions) with baited hooks suspended from the main line. The main line is frequently as long as 135 km and is stored on the vessel by one of two methods: A single large continuous spool (Fig. 3) or four large (2 m × 2 m × 3 m) storage bins. The bins are preferred by some vessel operators because they are apparently less dangerous, not requiring brakes to overcome the momentum of a large spool.

A gangion or branch line consists of four separate sections connected by swivels and splices (Fig. 4). The first section (connected to the main line) is approximately 12 m long, the second section ++ 0.1 m, and a third section 10 m long is connected to the final segment, a 4-m braided steel leader. The hooks vary in size according to the target species, with the larger hooks used for bluefin and the smaller hooks for yellowfin tuna.

The float lines used to suspend the main line range in length from 10 to 30 m. The floats are approximately 45 cm in diameter and made of blown glass or plastic. Fluorescent reflectors are used on some floats so they can be easily seen at night. A series of radar, light, and flag buoys are also connected to the main line for ease in locating direction and position of the main line. Figure 5 shows the positioning of radar and light buoys in a typical longline set.

The Automatic Reeling and Paying (ARP) apparatus (Fig. 6) is used in both the haulback and setting operation and each vessel is equipped with two ARP's one on the bow and one on the stern. The one on the bow is used to pull the main line from the water and coil it onto the forward conveyor belt. The stern ARP apparatus pulls the main line from either the large drum spool or the line holding bins located at the stern.

Bait usually consists of mackerel or saury approximately 25 cm in length and/or squid of about the same size.

Setting the Gear

The longline is set from the stern of the vessel at a speed of approximately 10 kn, beginning generally between

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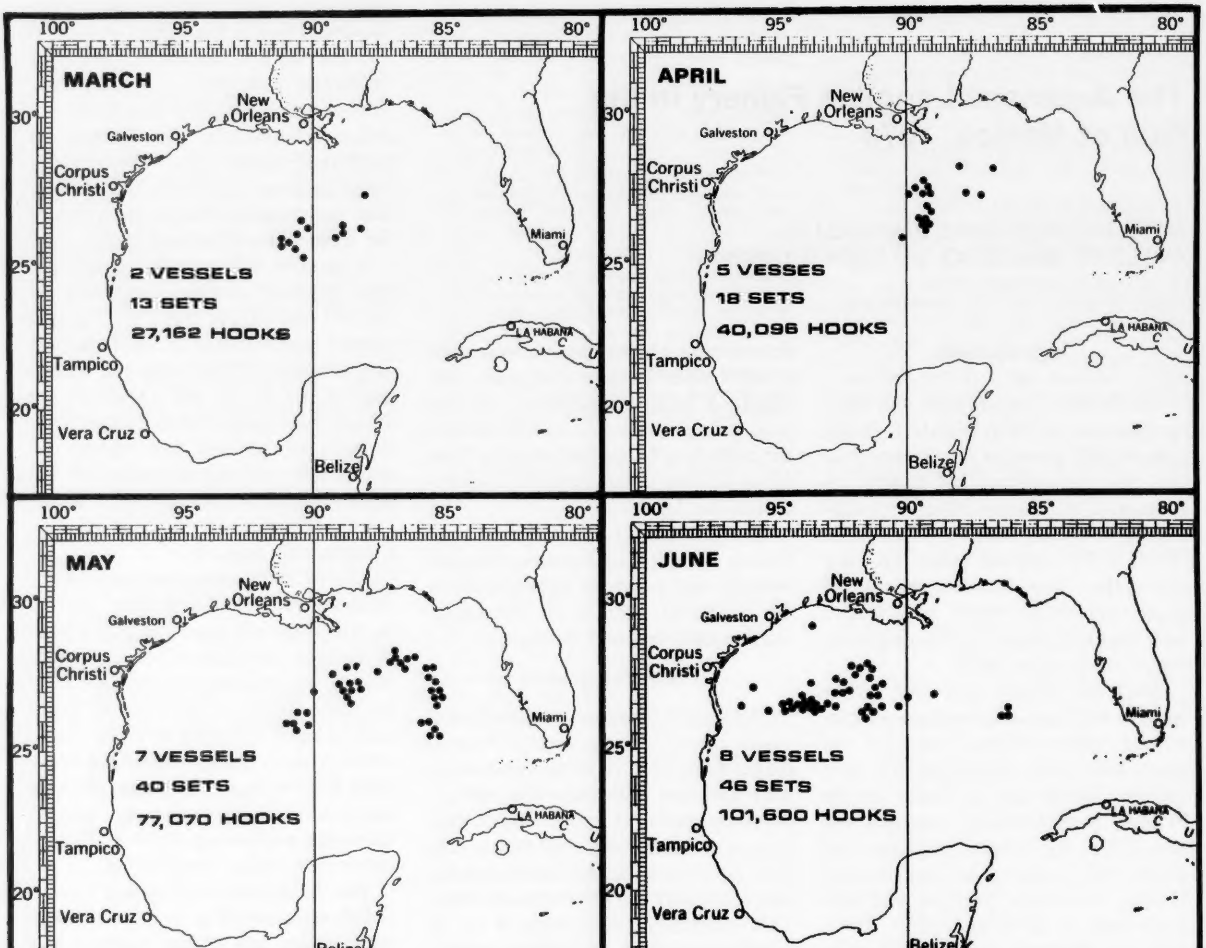

Figure 1.—Distribution of fishing effort by the Japanese longline fleet in the Gulf of Mexico in 1978 as recorded by U.S. observers. The points indicate only fishing effort sampled by U.S. observers and may not be proportionate to the total effort or actual distribution of the Japanese fleet. Each point, unless otherwise indicated, is a single set and each set averages about 2,000 hooks. Number of sets observed and number of vessels boarded are indicated on the figures.

Figure 2.—Typical Japanese longline vessel.

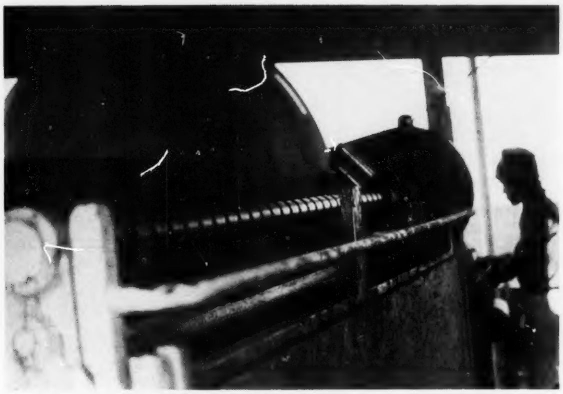

Figure 3.—Large metal spool used by Japanese longline vessels for storing the main line.

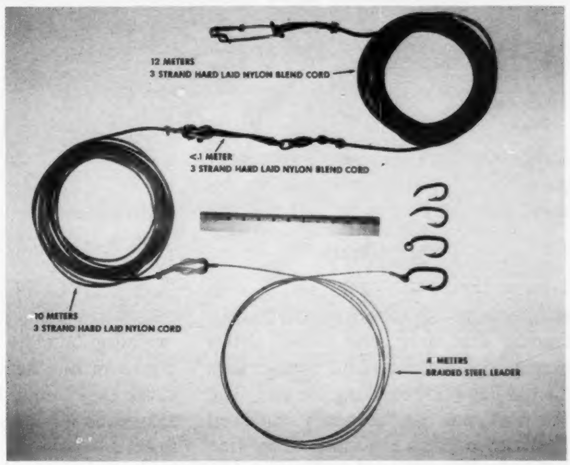

Figure 4.—Typical gangion used on Japanese longline as observed by one U.S. observer. Larger hooks are used for bluefin tuna while smaller hooks are used for yellowfin tuna.

2400 and 0200 hours and completed between 0800 and 1000 hours. There is a great deal of variation between vessels due to past or predicted fishing techniques and conditions. The number of hooks fished per set for bluefin tuna ranges from 1,923 to 2,228. Three to four gangions were spaced between floats. When fishing for yellowfin tuna, the number of hooks per set ranged from 2,283 to 2,391 and 4 to 5 hooks were fished between floats.

Five men are involved in setting the fishing gear. The main line passes through guides from the storage area to the ARP apparatus at the stern. One crewman uncoils the gangion or float line and hands the longline clip to a second crewman who attaches it to the main line. A third crewman then places the bait on the hook and throws the entire gangion or float overboard. The two remaining crewmen ready the bait, arrange gangions and floats on the aft conveyor belt, so the setting operation is continuous, and prepare light and radar buoys (Fig. 7). Some factors seemingly affecting the position and direction of the set were the surface temperature of the water, current direction,

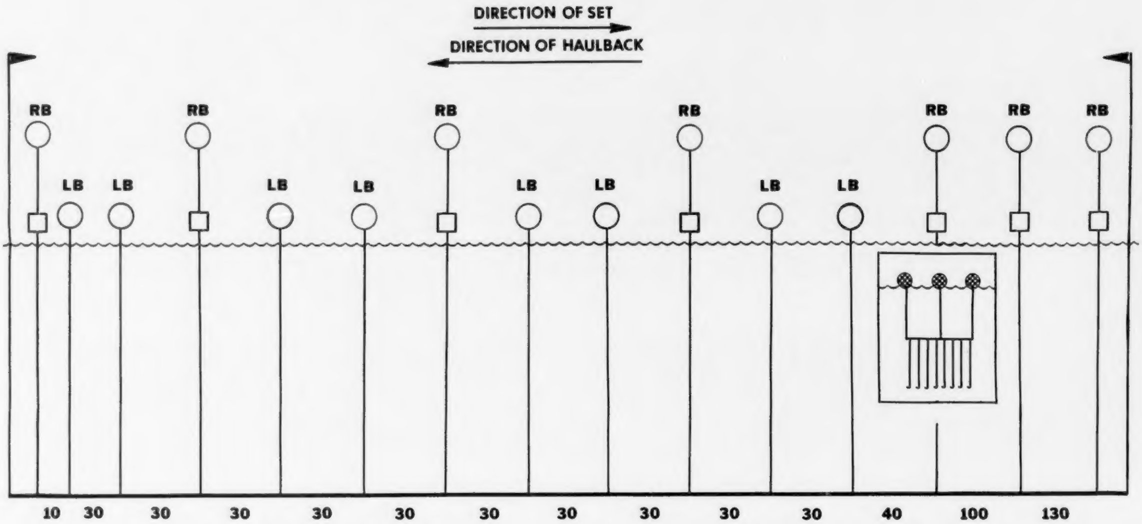

Figure 5.—Placement of radio (RB) and light (LB) buoys on a Japanese longline as observed by one U.S. observer aboard a Japanese longline vessel fishing in the Gulf of Mexico in 1978. Insert shows the placement of gangions between each float for this vessel. The number of floats between each light or radio buoy is indicated at the bottom. Directions of set and haulback are indicated also.

and past or predicted fishing success of the vessel or other vessels fishing in the same area.

The Haulback

After completion of the set, there is an interval of 4-5 hours before retrieval. During this time, the vessel drifts nearby, maintaining visual contact with the red flag buoy marking the end. The last hook put out is usually retrieved first, allowing the beginning of the line to fish the longest. In a few cases, however, depending on how fishing was the day before and how the line was set, the vessel steams to the beginning of the longline and begins the retrieve. In most cases, the haulback begins around noon, lasts for approximately 12 hours, and involves 10-12 crew members.

Once the red flag buoy is on board, the main line is immediately put on the forward ARP apparatus, and the vessel moves ahead about 4-6 kn parallel to the line. As the main line is retrieved by the ARP apparatus, it is coiled on the forward conveyor belt. From the conveyor belt, the line moves through a trough of seawater for rinsing, through metal separation guides on the fishing deck, through polyvinyl chloride pipe on the port side, and finally onto a coiler, which coils the line into storage bins, or the large drum spool. Also, as the main line is retrieved, the float lines, buoy lines, and gangions are unsnapped, coiled, placed in plastic tubs or tied in bundles, and carried aft on a conveyor belt for storage (Fig. 8). Because every crew member knows how to operate all equipment, they are able to set up a rotation throughout the haulback.

As soon as the haulback begins, or just before, the crew which set the line that night has freezer duty. This entails going into the flash freezer and removing frozen quarter fillets of bluefin and whole yellowfin tuna from the racks and putting them into the appropriate freezer compartment. Usually the fillets or whole tuna are kept in the flash freezer for 36-48 hours. This procedure is done every day to make room for that day's catch.

When a giant bluefin tuna is caught, the gangion is unsnapped from the main line and immediately attached to a safety line. Two or more men put a strain on the line as the boat stops or slows down. After handlining the tuna to the fish door, the bluefin is harpooned in the head if still alive and either tail

Figure 6.—Automatic reeling and paying apparatus. Device is used for hauling and setting the longline gear onboard Japanese longline vessels.

Figure 7.—Crewmen of a Japanese longline fishing vessel assembling gear during a set from the stern of the vessel.

Figure 8.—Crewmen on the fishing deck of a Japanese longline vessel disassembling the main line during a haulback.

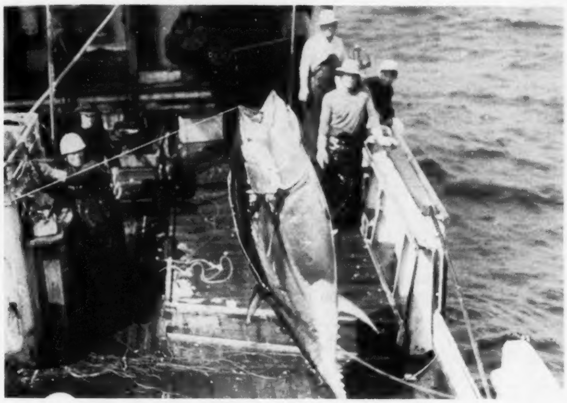

Figure 9.—Giant bluefin tuna being winched aboard a Japanese longline vessel in the Gulf of Mexico.

Figure 10.—Japanese longline crewmen filleting a giant bluefin tuna.

Figure 11.—Fillets of giant bluefin tuna being processed and prepared for going into flash freezer.

roped or gaffed and winched aboard (Fig. 9). All live giant bluefin tuna are harpooned to minimize the risk of losing the fish. For smaller fish, the vessel usually does not stop because the men are able to pull these fish in easily. Once on board, the giant bluefin tuna are filleted and divided into quarters (Fig. 10, 11). Each quarter fillet is trimmed of excess fatty and intermuscular tissue, placed on a wooden pallet, and taken into the flash freezer. On some vessels, two fillets from the same side of the fish are weighed and recorded on log sheets. Occasionally, the fillets are wrapped in plastic before being placed in the freezer. From boarding to freezer, the process takes no more than

Table 1.—Total catch by species by month as recorded by U.S. observers aboard Japanese longline vessels in the Gulf of Mexico in 1978. These numbers represent only a portion of the total catch by the Japanese longline fishery. BM=blue marlin; WM=white marlin; SF=sailfish; SP=spearfish; SW=swordfish; BF=bluefin tuna; YF=yellowfin tuna; OT=bigeye, skipjack, albacore, blackfin, and unidentified species; SH=silky, blacktip, whitetip, dusky, blue, tiger, hammerhead, mako, thresher, porbeagle, brown, and unidentified sharks; OF=dolphin, wahoo, king mackerel, lancetfish, oilfish, sunfish, opah, stingray, and other species.

Month	Unidentified billfish	BM	WM	SF	SP	SW	BF	YF	OT	SH	OF	Turtles	Total
March	0	1	4	0	0	22	79	29	6	12	18		171
April	0	3	4	1	3	13	257	21	3	71	25		401
May	0	11	28	21	2	30	309	64	0	142	126		733
June	3	34	226	30	13	59	49	1,451	56	160	359	2	2,442
July 1-17	9	60	535	66	74	88	1	2,498	276	253	626	4	4,490
Total	12	109	797	118	92	212	695	4,063	341	638	1,154	6	8,237

Table 2.—Number of sets and total number of hooks set by month by Japanese longline vessels recorded by U.S. observers. These numbers only represent a portion of the Japanese longline fishing effort in the Gulf of Mexico.

Month	Sets	Hooks
March	13	27,162
April	18	40,096
May	40	77,070
June	46	101,600
July 1-17	50	119,550
Total	167	365,478

Table 3.—Percentage of total catch by species by month of fishes caught by Japanese longline vessels as recorded by U.S. observers. These numbers do not represent the total catch by Japanese longline vessels in the Gulf of Mexico in 1978. See Table 1 for column definitions.

Month	Unidentified billfish	BM	WM	SF	SP	SW	BF	YF	OT	SH	OF	Turtles
March	0	0.58	2.34	0	0	12.86	46.20	16.96	3.51	7.02	10.53	0
April	0	0.74	1.00	0.25	0.75	3.24	64.90	5.24	0.75	17.71	6.23	0
May	0	1.50	3.82	2.86	0.27	4.09	42.15	8.73	0	19.37	17.19	0
June	0.12	1.39	9.25	1.23	0.53	2.42	2.01	59.42	2.29	6.55	14.70	0.08
July 1-17	0.20	1.34	11.91	1.47	1.65	1.96	0.02	55.63	6.15	5.63	13.94	0.09
Mean	0.15	1.32	9.68	1.43	1.12	2.57	8.44	49.33	4.14	7.75	14.01	0.07

Table 4.—Live (L), dead (D), and percent mortality (%M) by species by month of fishes caught by Japanese longline vessels in the Gulf of Mexico during 1978. These numbers represent only catch as observed by U.S. observers. This is not the total catch of the Japanese longline fishery.

	Blue marlin			White marlin			Swordfish			Sailfish			Spearfish			Unidentified billfish			Sharks			Other		
Month	L	D	%M	L	D	%M	L	D	%M	L	D	%M	L	D	% M	L	D	%M	L	D	%M	L	D	%M
March	1	0	0%	4	0	0%	8	14	64%	0	0	0%	0	0	0%	0	0	0%	8	4	33%	66	66	50%
April	0	3	100%	3	1	25%	3	10	77%	1	0	0%	1	2	67%	0	0	0%	57	14	20%	70	46	40%
May	10	1	9%	20	8	29%	11	19	63%	6	15	71%	0	2	100%	0	0	0%	123	19	13%	177	322	64%
June	24	10	29%	102	124	55%	14	45	76%	19	11	37%	5	8	61%	1	2	67%	138	22	14%	572	1,343	70%
July 1-17	18	42	70%	203	332	62%	21	67	76%	30	36	54%	20	54	73%	7	2	22%	210	43	17%	792	2,609	77%
Total	53	56	51%	332	465	58%	57	155	73%	56	62	52%	26	66	72%	8	4	33%	536	102	16%	1,677	4,368	72%

7 minutes. Other tunas are processed differently. Instead of filleting, these fish are gutted, fins and tails cut off, and gills and gill plates removed. The body cavity and outside of the fish are cleaned and washed down with a scrub brush before freezing.

Catch Composition

During the 1978 longline season in the Gulf of Mexico, the vessels observed captured a total of 8,237 fish and 6 turtles (Table 1). The target species from 1 March to 1 June was bluefin tuna; yellowfin tuna was the target species from 1 June to 17 July. From 1 March to 17 July, 167 sets of longline gear were monitored totaling 365,478 hooks (Table 2). The composition of the catch changed significantly during the season (Table 3). This change was not only between the target species (bluefin from 1 March to 1 June, yellowfin from 1 June to 17 July), but among the incidental catch as well. The catch of blue marlin and white marlin, for example, was low early in the season, but increased significantly as the season extended into the summer months (Table 4).

Acknowledgments

The collection of biological samples from bluefin tuna was accomplished through the cooperation of the Japanese fishing companies. We gratefully acknowledge their assistance, and we appreciate the courtesies extended to us by the various fishing vessels. The authors thank Grant L. Beardsley for his direction in writing this paper.

Boston Fish Pier Landings, 1978: A Review

DONALD A. JERPI

Off-loading pollock at low tide. (Boston North End in background.)

Introduction

Boston Fish Pier landings in 1978 were the heaviest since 1974 when 28.5 million pounds were landed. The 1978 value was the highest since 1967 when 77.9 million pounds landed brought $9.6 million to the fishermen.

As was the case in other New England ports, Boston had some new vessels join the fleet in 1978. These new vessel additions were partially responsible for the slight increase in the total number of trips landed in 1978. Also many of the vessels made trips of shorter duration, 5- or 6-day trips, rather than 10- to 12-day trips. The shorter trips made it possible for the vessels to make more trips. The most active vessel made a total of 46 trips during the year. Two new vessels were scheduled to join the fleet in March 1979 and additional vessels later in the year.

Fishing quotas were adjusted many times during the fishing year on the recommendation of the New England Fisheries Management Council with the approval of the Department of Commerce. These adjustments were deemed necessary to avoid placing undue hardship on the fishing industry, keeping in mind the plight of the various regulated fish stocks.

Fish Pier Landings Increase

A total of 651 groundfish trips sold 27.3 million pounds of fish through the New England Fish Exchange at the Boston Fish Pier in 1978, valued ex-vessel at $8.1 million (Table 1). This was a 5.1-million-pound increase over the 1977 landings of 22.2 million pounds from 591 trips, valued at $6.0 million. The 23 percent increase in landings in 1978 was due to two reasons: 1) The increased number of trips by large and medium otter trawlers landed at Boston (Table 2) and 2) the turning back of the quota clock in October resulted in the landing of 7.3 million pounds of fish from October through December (Table 3). Commencement of a new fishing year for quota purposes began 1 October 1978. The landed weights of all species was up except for blackback and lemon sole flounders (Table 1). The blackback flounder landings were off mainly due to the decrease in the total number of small inshore otter trawler trips. The decrease in lemon sole landings was partially due to the haddock quotas—vessels spent less time fishing eastern Georges Bank where most of the lemon sole are normally caught.

The 1978 total ex-vessel value rose 35 percent from 1977. The increased landings and higher ex-vessel prices of all species except large and market cod, and large haddock were accountable (Table 4).

Cod

This was the leading species landed in Boston again in 1978 with 9.9 mil-

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lion pounds (36 percent of the total landings), up 15 percent from 1977's landings of 8.6 million pounds. The value gained 27 percent due to the increase in landings. For five different months the landings were over a million pounds (Table 3). On 26 December record ex-vessel first-sales prices were established on the three sizes of cod—large 95¢ per pound (average for the year was 29.87¢), market cod $1.00 (annual average was 31.92¢), and scrod cod $1.01 (annual average 30.65¢).

Haddock and Scrod

Large haddock landings of 2.7 million pounds, valued at $1.1 million ex-vessel in 1978 were up compared with the 2.2 million pounds in 1977 which also sold for an ex-vessel value of $1.1 million. The total landings might have been higher if the Canadian Government had not banned U.S. vessels from fishing in northwest Atlantic Canadian waters (Subarea 4X) after 4 June. The 1978 value remained about the same as in 1977 due to the decrease in the average ex-vessel price paid for large haddock—47.86¢ a pound compared with the previous year's average of 53.78¢. The price drop was due mainly to the larger amounts of large haddock landed in February. Haddock prices also set a new record high when the first-sales ex-vessel price reached $1.41 a pound on 26 December.

Haddock scrod landings of 4.7 million pounds in 1978 were up 29 percent from the previous year's landings of 3.7

Table 1.—Boston Fish Pier landings by species, 1978 and 1977 (landings in round weight).

Species	1978 Pounds	1978 $/Value	1978 Avg. ex-vessel prices (¢/lb.)	1977 Pounds	1977 $/Value	1977 Avg. ex-vessel prices (¢/lb.)
	... In 1,000 ...			... In 1,000...		
Cod	9,926	2,630	—	8,655	2,071	—
Large	—	—	29.87	—	—	32.23
Market	—	—	31.92	—	—	32.18
Scrod	—	—	30.65	—	—	22.47
Cusk	334	76	25.87	232	46	22.51
Haddock, large	2,724	1,142	47.86	2,268	1,067	53.78
Haddock, scrod	4,732	1,628	39.26	3,663	1,056	32.87
Hake, white	539	109	27.50	509	98	25.77
Pollock	4,336	920	23.97	3,314	600	20.34
Ocean perch	2,794	629	22.52	2,184	451	20.72
Flounders						
Blackback	392	186	47.30	398	148	37.24
Dab	497	269	54.02	323	143	44.25
Sole, gray	252	164	65.12	135	81	60.15
Sole, lemon	43	26	55.49	45	20	42.77
Yellowtail	406	197	48.69	336	157	43.34
Halibut	3	5	187.35	1	2	143.89
Whiting	—	—	—	9	1	13.62
Wolffish	235	32	16.80	176	18	12.10
Scallops, sea (meats)	19	46	250.00	—	—	—
Unclassified	44	12	25.96	3	1	20.13
Totals	27,276	8,071	33.35	22,251	5,960	30.26

Table 2.—Trips by month, type and size of gear, and total landings and value.

Month	Gear: Otter trawlers Large	Medium	Small	Line trawlers	Other vessels	Total 1978	Monthly totals: Trips 1977	1978 Landings	1978 $/value
								. . . (In 1,000) . . .	
January	11	20	13	4	—	48	53	1,304	500
February	15	16	4	2	—	37	40	2,652	726
March	15	24	5	1	—	45	31	1,932	666
April	11	24	11	1	—	47	37	1,843	460
May	11	32	8	1	—	52	45	1,741	418
June	7	37	12	—	—	56	58	2,240	464
July	9	37	9	—	[1]1	56	52	1,867	578
August	18	54	5	3	—	80	73	3,368	1,017
September	22	38	9	3	[2]1	73	50	3,058	966
October	24	29	10	—	—	63	64	3,169	926
November	18	30	2	—	—	50	48	2,577	764
December	16	26	2	—	—	44	40	1,525	586
Totals 1978	177	367	90	15	2	651	—	27,276	8,071
1977	166	238	129	58	—	—	591	22,251	5,960

[1]Scalloper.
[2]Seine boat.

Table 3.—Boston, Mass., fishery landings by month, species, and value.

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	$/Value
						In 1,000 lb.							. . In 1,000 . .	
Cod, mixed	400	1,107	549	626	868	1,157	518	1,031	1,125	1,491	800	254	9,926	2,630
Cusk	6	8	23	17	10	23	26	43	47	52	42	37	334	76
Haddock, large	123	507	168	68	67	156	223	381	281	266	354	130	2,724	1,142
Haddock, scrod	403	572	299	302	213	307	355	869	532	461	320	99	4,732	1,628
Hake, white	8	11	22	15	8	22	30	35	124	97	110	57	539	109
Pollock	153	194	466	390	196	225	274	585	452	444	514	443	4,336	920
Ocean perch	25	93	261	190	227	221	351	247	329	206	276	368	2,794	629
Flounders														
Blackback	103	76	50	22	18	11	8	11	48	29	11	5	392	186
Dab	8	20	26	63	36	47	26	46	42	58	54	71	497	269
Sole, gray	6	6	18	41	23	20	13	14	19	14	36	42	252	164
Sole, lemon	14	10	4	5	2	1	—	—	—	3	4	—	43	26
Yellowtail	42	29	27	41	37	24	8	84	28	32	43	11	406	197
Halibut	—	—	—	—	—	—	—	—	1	1	1	—	3	5
Scallops, sea	—	—	—	—	—	—	19	—	—	—	—	—	19	46
Wolffish	13	19	19	63	36	25	12	18	8	6	8	8	235	32
Bluefish	—	—	—	—	—	—	—	—	14	—	—	—	14	1
Unclassified	—	—	—	—	—	1	4	4	8	9	4	—	30	11
Total landings (1,000 lbs.)	1,304	2,652	1,932	1,843	1,741	2,240	1,867	3,368	3,058	3,169	2,577	1,525	27,276	—
Total value ($1,000)	500	726	666	460	418	464	578	1,017	966	926	764	586	—	8,071

million pounds. The landings would have been greater if there had not been catch restrictions imposed by the Fishery Management Plans. It had been reported that fishermen spent as much time steaming away from haddock scrod as they spent fishing for them. When they arrived at a new fishing area they were unable to continue fishing as they again found more haddock scrod than they were permitted to catch. The total ex-vessel value of the haddock scrod landings in 1978 was $1.6 million as compared with the previous year's total value of $1.1 million. The average ex-vessel price for haddock scrod in 1978 was 39.26¢ a pound, however, the first-sales price reached a record high on 26 December when scrod was bid up to $1.30 a pound. This year's landed value was up 45 percent due to this year's average ex-vessel price of 39.26¢, an increase of 6.39¢ a pound from 1977's average of 32.87¢.

One of the reasons for the 1978 increase in large and scrod haddock landings was attributed to the weekly quota that was established and the amount allowed for overrun compared with the trip quotas per vessel in 1977.


Fishing vessel *Eleanor Eileen* off-loading groundfish trip at Boston Fish Pier.

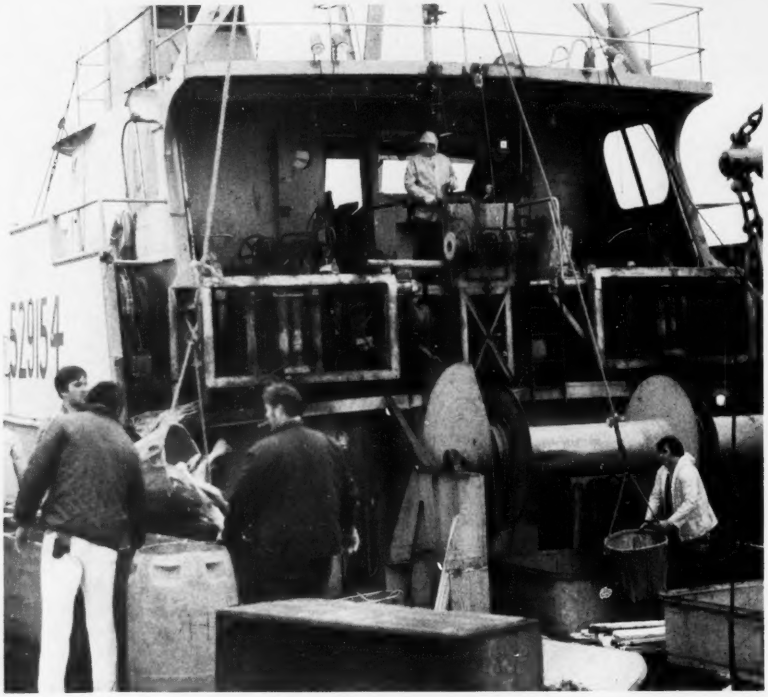
Many vessels fished for the weekly limit and the allowed overrun—some vessels even recommended the establishment of a 3-week fishing period. Some of the fishermen had mentioned that the quotas should be set according to the number of crew members because a medium otter trawler that fishes on Georges Bank has about the same expenses as a large vessel—both go to sea with 6-8 crewmen.

Pollock

Pollock ranked third in volume of landings at Boston in 1978 with a total of 4.3 million pounds, up 31 percent

Table 4.—Boston, Mass., ex-vessel prices by month and species (landed weight) and yearly average ex-vessel prices ($/cwt.).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1978	1977
No. of trips	48	37	45	47	52	56	56	80	73	63	50	44	651	591
Cod														
Large	39.57	27.23	35.22	26.26	22.33	18.33	30.76	29.48	34.00	28.90	33.01	51.90	29.87	32.23
Market	36.00	31.04	43.78	25.10	25.31	21.10	39.41	38.89	36.51	29.61	36.20	58.31	31.92	32.18
Scrod	35.78	28.52	39.14	25.14	22.37	20.38	39.21	39.06	35.16	29.39	34.74	55.44	30.65	22.47
Cusk	39.64	27.69	33.42	21.28	24.60	15.77	20.94	23.98	25.26	22.79	27.60	36.53	25.87	22.51
Haddock, large	57.61	37.86	56.10	50.82	57.42	41.00	41.15	49.64	52.16	48.18	42.40	79.95	47.86	53.78
Haddock, scrod	44.65	30.57	51.78	39.09	35.54	27.20	34.85	37.90	41.77	40.98	40.66	76.03	39.26	32.87
Hake, white	58.40	49.19	49.23	45.50	42.77	20.67	23.61	21.82	18.77	23.61	24.91	42.28	27.50	25.77
Pollock	28.50	24.63	27.84	22.02	25.26	22.97	24.99	21.65	27.32	24.46	20.68	22.02	23.97	20.34
Ocean perch	36.67	21.51	23.54	20.31	19.93	17.92	20.40	22.78	21.23	26.16	24.01	26.35	22.52	20.72
Flounder														
Blackback	48.39	42.04	47.60	30.74	36.86	33.67	54.90	49.07	53.23	66.02	52.29	48.31	47.30	37.24
Dab	72.02	49.11	64.08	29.18	31.35	35.64	59.72	62.98	69.56	64.61	55.87	69.36	54.02	44.25
Sole, gray	96.46	53.31	77.90	46.42	39.65	40.58	66.57	67.52	75.67	81.08	70.53	85.05	65.12	60.15
Sole, lemon	69.68	48.04	51.04	28.50	57.28	50.00	—	—	—	63.59	57.73	58.00	55.49	42.77
Yellowtail	64.39	50.44	59.64	32.41	39.43	34.38	61.68	36.15	68.74	65.54	51.93	50.00	48.69	43.34
Halibut	—	176.61	—	—	—	—	—	175.00	169.44	200.00	200.00	—	187.35	143.89
Whiting, rnd.	—	—	—	—	—	—	—	—	—	—	—	—	—	13.62
Wolffish	22.95	15.98	20.64	14.23	14.54	12.07	18.96	19.28	20.19	23.29	21.84	24.17	16.80	12.10
Scallops, sea	—	—	—	—	—	—	250.00	—	—	—	—	—	250.00	—
Value ($1,000)	500	726	666	460	418	464	578	1,017	966	926	764	586	8,071	5,960
Total landings (1,000 lb. rnd. wt.)	1,304	2,652	1,932	1,843	1,741	2,240	1,867	3,368	3,058	3,169	2,577	1,525	27,276	22,251
Average ex-vessel price	43.18	31.16	38.52	27.94	27.01	23.43	32.05	34.14	35.76	33.30	33.54	33.19	33.35	30.26



Off-loading cod from fish holds by winch.

from the previous year's total of 3.3 million pounds. The 1978 value of the pollock landings totaled \$0.9 million, 54 percent above the 1977 value of \$0.6 million. The gain in value was attributed to the heavier increase in the average ex-vessel price from 20.34¢ the previous year to 23.97¢ in 1978. Again, August was the month of heaviest pollock landings totaling 585,000 pounds compared with August 1977 with only 421,000 pounds (Table 3). The August 1978 average ex-vessel price of 21.65¢ (Table 4) was below the annual average of 23.97¢ a pound, but higher than that for 1977 of 20.34¢ (Table 1). The 1976 pollock annual average ex-vessel price was only 18.97¢ when 5.6 million pounds were landed.

Ocean Perch

Ocean perch landings in 1978 of 2.8 million pounds were up 28 percent from 1977's 2.2 million pounds. The 1978 landings might have been higher except that some of the vessels that landed ocean perch in Boston in previous years unloaded in Gloucester although some

Off-loading cod and ocean perch from Boston "highliner."

of the fish were shipped to Boston by truck.

Hake

Hake landings in 1978 of 539,000 pounds were up 6 percent from the previous year's landings of 509,000 pounds. A record high first-sales price was established for hake when 80¢ a pound was recorded on 26 December. The year's average ex-vessel price of 27.50¢ showed a slight increase over 1977's average of 25.77¢.

Cusk

Cusk landings of 334,000 pounds in 1978 were valued at $76,000 compared with the previous year's 232,000 pounds valued at $46,000. The average ex-vessel price in 1978 of 25.87¢ a pound was up from the 22.51¢ average the previous year.

Flounder

Flounder landings of 1.6 million pounds valued at $0.8 million increased 28 percent in quantity and 53 percent in value compared with the previous

"Lumper" off-loading fish into 500 pound boxes.

Three boxes of ocean perch being weighed up by Massachusettes Port Authority scaleman; vessel checker to left of weighing staion is recording weight

year's total landings of 1.2 million pounds valued at $0.5 million. The leading flounder species landed was dabs—497,000 pounds, valued at $269,000, up 54 percent in quantity and 88 percent in value. A record first-sales price of $1.42 a pound was established for dabs. The annual average ex-vessel price for dabs was 54.02¢ in 1978 and 44.25¢ in 1977. Total landings of all species of flounder were up except for blackbacks (down 2 percent because of a decrease in the small otter trawler fleet) and lemon sole (down 4 percent because of the haddock quota—the trips spent less time on eastern Georges Bank). Other flounders landed and values were: Yellowtail, 406,000 pounds valued at $197,000 (with record first-sales price of 95¢); blackbacks, 392,000 pounds valued at $186,000; gray sole, 252,000 pounds valued at $269,000 (record first-sales price of $2.00); and lemon sole, 43,000 pounds valued at $26,000.

Scallops

One scalloper landed a total of 19,000 pounds of sea scallops, valued at $46,000 in the month of July. Although it was rumored that other scallopers would unload in Boston, it never occurred.

Vessel Information

The medium size otter trawler, *Eleanor Eileen,* joined the Boston fleet in 1978 and her maiden trip landed 1 August. The same owners had two other vessels, *Eleanor Eileen II* and the *Eleanor Eileen III,* built in St. Augustine, Fla., which were expected to join the Boston fleet in March 1979. Also two new Gloucester vessels, the *Paul & Domenic* and the *Vito C,* landed trips in Boston in 1978.

The small vessel, *Salvi & Joe,* sank at the dock but was raised and sold to a New Bedford interest in January. However, it sank a second time at the dock during the February "Blizzard of '78." Again, it was raised and has since departed for an unknown destination.

For various reasons, nine vessels that had landed a total of 43 trips in 1977, failed to land any trips in 1978 at the Boston Fish Pier. Were it not for the decrease in the line trawler and small otter trawler trips along with the other vessels previously mentioned, Boston might have had well over 700 trips in 1978.

Other Information

The Channel Fish Company closed its facilities on the Fish Pier in July and moved to East Boston, although it continues to buy fish through the New England Fish Exchange. The D&F Fish Company moved into the facilities vacated by the Channel Fish Company at 31 Fish Pier.

Future Expansion

A complete revitalization of the Boston Fish Pier was expected to commence in the spring of 1979 and continue over the next 3 years at a cost of $10 million. The Massachusetts Port Authority also plans to renovate the neighboring Commonwealth Pier at a cost of between $10 to $20 million. Future plans for the Commonwealth Pier do not include its use by the fishing industry.

Fishery Outlook Brightest in 25 Years, NOAA Official Says

The Fishery Conservation and Management Act has provided the U.S. fishing industry its brightest outlook in 25 years, James P. Walsh, Deputy Administrator of the National Oceanic and Atmospheric Administration, has pointed out.

In testimony before the House Subcommittee on Fisheries and Wildlife Conservation and the Environment of the Merchant Marine and Fisheries Committee, Walsh stated that domestic commercial fishermen landed a record 2.8 million metric tons (t) with a dockside value of $1.9 billion in 1978 which was a 16 percent increase over 1977 landings and a 22 percent increase in value over 1977.

Citing investments of over $200 million in processing plants, vessels, and fishing gear in Alaska and the 54 percent increase in fishing vessels in New England, Walsh said the Act has developed a favorable investment climate in most sectors of the fishing industry.

"The number of foreign fishing vessels off our shores has been slashed from over 2,700 in 1975 to about 600 fishing vessels in 1978," Walsh said. "The Act also has reduced the foreign catch within our 200-mile fishery conservation zone to about 1.7 million t in 1978 from a high of 3.5 million t in 1971."

The Department of Commerce official told the lawmakers that the implementation of the Act has not been without thorny problems which still need to be resolved. He cited complications encountered in producing a management plan for salmon in the Northwest, difficulty of implementing the groundfish plan in New England, and the lack of certain information in the butterfish plan for the east coast, causing the Council's plan to be disapproved, as some of the major issues encountered.

"We also have been faced with problems that are generic to the fisheries conservation and management regime established by the Act," said Walsh. "The Act clearly provides for regulation of both domestic and foreign fishermen; however, many fishermen did not understand that the management provisions of the Act applied to them. There have been and will continue to be situations in which domestic fishing must be tightly managed to prevent overfishing," he said.

Walsh told the committee that during the past year the Department had been trying to improve the management system by reducing complex regulations and lengthy planned review procedures.

A New Seabed Mining Law Could Protect Marine Life, Allow Mineral Extraction

Richard A. Frank, Administrator of the National Oceanic and Atmospheric Administration (NOAA), has said that the U.S. should be able to draw vital raw materials from the deep sea floor and also assure protection of the ocean environment. In testimony before the House Merchant Marine and Fisheries Committee's Subcommittee on Oceanography in June, Frank voiced the Administration's support of deep seabed mineral legislation, and outlined additional measures that would make ocean mining ventures environmentally sound.

Frank pictured a "thriving deep seabed mining industry" by the mid-1990's taking up significant quantities of raw minerals from the ocean bottom and providing "a stable future supply . . . with reduced risk of supply disruptions and unreasonable price fluctuations." Deep seabed mining, said Frank, could result in limiting price increases of certain raw materials, thus helping to dampen inflation, reduce the unfavorable balance of payments, and promote development goals of developing nations.

Frank called for a change in proposed House Bill H.R. 2759 to require miners to submit a work plan as part of their application process. By knowing in advance what actions they propose, appropriate precautions could be taken to prevent undesirable impacts on the resource or the environment, Frank explained.

He also asked that environmental impact statements be completed before any license or permit is approved. The NOAA Administrator explained that this would permit the Government to determine if proposed exploration or recovery activities would "pose an unreasonable threat to the quality of the environment."

With these environmental protections, Frank explained, the Administration "agrees that deep seabed mining

can be commenced before all environmental research is completed." Otherwise, he stated, the program could be delayed for 10 or more years.

"However, if we are to allow activities to begin and operate before ocean research is completed," Frank told the Committee, "the bill must provide the flexibility to modify or change regulatory requirements in light of future research." For that reason Frank asked that the bill be changed to ease limitations on the authority to make appropriate modifications in license permits if future research revealed such a need.

Frank also urged that the bill grant the Government the power to suspend or modify particular mining activities without necessarily having to close the total mining operation, as the bill now provides. "Seabed mining is a costly endeavor," Frank acknowledged, "and shutting down the entire operation could be extremely expensive to the miner and often unnecessary as lesser alternatives would be available."

Frank went on to note that NOAA "has made substantial progress in assessing the potential environmental effects of deep seabed mining." He pointed out that the Deep Ocean Mining Environmental Study (DOMES) has "resolved some of the environmental concerns voiced during the early 1970's," since it is now possible to estimate the extent of short-term effects.

NOAA's DOMES project began in 1972 by developing environmental baselines in areas of the ocean where mining likely would take place. A later phase, still underway with the close cooperation of industry, is monitoring industrial tests of demonstration-scale nodule recovery equipment. The information now being acquired will be used "to start assessments of long-term, chronic, and cumulative impacts," Frank said, adding that many of the remaining questions would be answered in the next 1½ years. DOMES activities now underway, he pointed out, involve refined prediction capabilities, environmental guidance, and assessments of the ocean's ability to recover from the mining.

NOAA is working with the Environmental Protection Agency and the Bureau of Mines, Frank said, on a research plan to deal with problems of onshore or at-sea waste disposal. Early systems, he indicated, will probably depend upon shore-based processing.

NOAA has also supported research at the Massachusetts Institute of Technology to produce a cost model for deep ocean mining. The MIT study, now being refined, has already been used by the Departments of State and Treasury as well as NOAA in assessing Law of the Sea proposals and domestic tax alternatives.

Chesapeake Bay Oyster, Blue Crab Declines Eyed

Declines in oyster production and fluctuations of crab harvests in the Chesapeake Bay are being studied this year by University of Maryland scientists under a $725,900 grant from the National Oceanic and Atmospheric Administration (NOAA), Secretary of Commerce Juanita Kreps has announced. The research effort is one of 24 projects supported at the university under the Commerce agency's National Sea Grant College Program, which provides financial assistance to colleges and universities for research in marine resources. The NOAA grant will be supplemented by $537,050 in non-Federal matching funds.

The Maryland oyster fishery, which produces one-third of the Nation's output, has been declining in production since the turn of the century. Yields of 10-15 million bushels annually in the late 1880's have fallen to less than 1.5 million bushels in the mid-1960's.

Efforts of the State's Department of Natural Resources resulted in an increase to 2.5-3 million bushels yearly in the early 1970's, but the fishery faces new problems because the oysters are failing to reproduce in sufficient numbers. These latest declines could result in serious consequences for Maryland watermen, according to the scientists, unless natural reproduction is improved.

The oyster fishery in Maryland is the backbone of the State's fishing industry, with approximately 9,000 persons, directly or indirectly, dependent on it for their livelihood.

The blue crab studies will investigate the sources of the population—whether young crabs come primarily from estuarine waters near the mouth of the Chesapeake or Delaware Bay, as most people believe, or whether offshore larvae serve as a source of recruitment. The scientists will also investigate the effect of parasitic and other organisms on the growth and reproductive rates of the crab.

The NOAA grant will provide support for additional research projects dealing with environmental quality of Bay waters, microbial populations that affect biofouling of natural surfaces and man-made structures, the chitin content of water and sediment in the bay, and the development of a molluscan cell line to enhance the study of molluscan diseases, nutrition, and biochemistry.

U.S.-French Marine Programs Continued

Plans for continuing U.S.-French cooperative programs in oceanographic research have been announced jointly by the United States and France.

Gerard Piketty, Director-General of France's National Center for the Exploitation of the Oceans (CNEXO), and Ferris Webster, NOAA's Assistant Administrator for Research and Development, outlined the plans following a 3-day meeting in Washington, D.C., earlier this year. The collaboration has been under way since 1970.

Programs to be undertaken represent a balance between basic and applied research, and are designed to enable each nation to take advantage of the special skills, knowledge, and facilities of the other for their mutual benefit.

In addition to agreed-upon programs in 10 specific areas of current cooperation—joint man-in-the-sea projects, marine geology and geophysics research, ecological assessment of the *Amoco Cadiz* disaster, marine pollution, aquaculture programs, coastal sediment dynamics studies, bilateral climate research and data gathering, ocean instrumentation, data buoy technology, data exchange—it was also agreed to initiate discussions in ocean thermal energy conversion and in bioconversion, with a view toward possible future cooperation in those areas.

DMA, Fish Quality Changes Are Studied

The formation of dimethylamine (DMA) in fresh, frozen, and dried fishery products has been given increasing attention by chemists concerned with reactions linked with undesirable changes in quality. Early research by Japanese and Canadian investigators showed that in gadoid species, such as hake, pollock, and cod, both DMA and formaldehyde form when trimethylamine oxide (TMAO), a common nitrogenous component of fish muscle, is degraded. Studies with fresh and frozen fish included observations of the effect of kidney, pyloric caeca, and blood in catalyzing or accelerating DMA formation in fish flesh. The evidence seemed to indicate that DMA formation was initiated by endogenous enzyme(s), but no specific enzymes were demonstrated or isolated.

The several studies by the Utilization Research Division at the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash., and others have shown that DMA formation during frozen storage of gadoids might be important as a quality index. Further, formaldehyde, which is formed along with DMA, reacts with proteins that in turn may produce undesirable textural change such as dryness or toughening of Alaska (walleye) pollock after lengthy cold storage. Currently, research is being conducted in the Division's laboratory on the relation between the breakdown of TMAO to DMA and formaldehyde and changes in texture of pollock muscle stored frozen. Additives that retard (such as hydrogen peroxide) or accelerate (such as sulfur dioxide and ethylenediamine tetraacetic acid) the degradation of TMAO are being tested in pollock.

In one approach, the effects are being monitored by determination of the extractable muscle protein, as a measure of protein change during frozen storage. In a second approach, formaldehyde labeled with $carbon_{14}$ is being used to estimate the rate of binding of formaldehyde to the muscle protein of minced pollock held at 0°C. Such studies may well demonstrate the nature of the undesirable changes in texture and reveal practical methods of inhibiting the changes, thereby improving quality. Because DMA can be nitrosated readily to dimethyl nitrosamine, the above work emphasizes the importance of the selection of handling and processing procedures to insure the safety as well as the quality of fresh, frozen, and dried fishery products.

Marine Life Thrives in Arctic Winters

Teams of diver-scientists, probing the near-total darkness and -35°F temperatures under the Arctic ice pack, have discovered some forms of marine life which, contrary to the conventional belief, appear to thrive in the harsh conditions about them. Working under contract to the National Oceanic and Atmospheric Administration (NOAA), marine biologists explored under the pack near Prudhoe Bay, Alaska, from November 1978 until May 1979.

The winter under-ice study, first of a series of investigations lasting through the next 2 years as part of NOAA's Outer Continental Shelf Environmental Assessment Program, was designed to provide an understanding of the life forms and cycles of the Bering Sea, and how they might be affected by offshore oil and gas development there. The scientists took samples, searched for eggs and larvae of key marine species, placed current meters under the ice, and assessed sediments and bottom-dwelling organisms.

"The Arctic winter months are not the biological standstill period we once thought," said David Norton, a scientist with the Commerce Department agency. Many organisms, he said, not only do not retreat from the hazards of winter under the ice, but appear to go about growing, reproducing, finding food, and generally ignoring the threatening conditions.

"No one else had looked at this ecosystem systematically in winter," Norton said. "But offshore oil and gas development must proceed during 9 months of ice cover, and we needed to know if it is advisable to dump drilling muds and cuttings, for example, into the water column or out on the ice, or whether this material must be hauled ashore.

"Ecologically, we needed to know more about overwintering organisms so we don't let environmental changes tip the balance against them during what may be the most difficult period in their annual cycle."

The assessment program is managed by NOAA for the Department of the Interior's Bureau of Land Management. Scientists from the University of Alaska, the Alaska Department of Fish and Game, Western Washington State University, Oregon State University, the U.S. Geological Survey, and a private environmental consulting firm, participated in the study.

Preserving Fresh, Whole Herring in Modified RSW

On the U.S. Pacific Coast, fresh herring for food processing (roe) are normally transported in refrigerated sea water (RSW) aboard a tender to the plant. In general, maximum storage life under commercial conditions in RSW is 4-5 days.

Earlier this year, a preliminary experiment was conducted by the Utilization Research Division of the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash., with one lot of relatively immature herring caught in Puget Sound, Wash., to compare keeping quality in ice (control) with modified RSW to which carbon dioxide was added. The iced herring spoiled in about 5 days while the herring in RSW-CO_2 appeared to be in good condition after 8 days, although the brine had developed off-odors at that time.

The RSW-CO_2-held herring showed no significant autolysis of the belly cavity or softening of adjacent flesh. The gain of 2-3 days in storage life could enable the industry to land herring of better quality and make better use of the carcass for food after the roe is removed. However, the scientists cautioned that additional tests should be conducted with other lots of herring before drawing definitive conclusions.

The Belgian Market for Fishery Products

Belgium's small fishing industry has had stable catches for the past several years (Table 1). Domestic landings, however, provide only about one-third of the country's total supply of fishery commodities, and imports of edible fishery products have averaged over 100,000 metric tons (t) annually since 1973. Prospects for increased domestic catches are poor because traditional coastal fishery resources are depleted and catch allocations severely restrict local fishermen. Belgium thus appears to be an excellent, if small, potential market for increased U.S. fishery exports. Such exports in 1976 totaled only 2,800 tons, valued at $12.6 million, or 2.5 percent in volume and 10 percent in value of total Belgian fishery imports.

Fleet and Catch

Belgian fishing vessel numbers have been declining since the 1950's. The fleet in 1978 was comprised of 215 vessels with a total of 20,700 GRT. Most Belgian fishing vessels are small; only 89 have a capacity exceeding 100 GRT. When compared with vessels owned by fishermen from other members of the European Economic Community (EEC), the Belgian fleet appears unusually small (Table 2). Belgium, unlike other EEC countries, has virtually no distant-water fishing fleet. Fishing is done almost exclusively in coastal waters by small, owner-operated vessels.

The Belgian fisheries catch since 1974 has been relatively stable, rising gradually to 51,000 t (Table 3). In 1978, Belgian fishermen landed 48,000 t of demersal fish, accounting for about 96 percent of the country's total catch. Cod is by far the predominant species fished; its 1978 landings totaled over 19,000 t, or nearly 40 percent of the total Belgian catch. Cod was the only species whose landings increased substantially in 1978. Most of the increase, however, was due to larger catches of young cod. EEC authorities believe that cod is over fished in this area, and that last year's increased landings cannot be sustained.

The NMFS Division of Foreign Fishery Analysis prepared this report.

Domestic Market

The annual per capita consumption[1] of fishery products in Belgium is estimated at about 18 kg, near the west European yearly per capita average of 19 kg, but higher than the 15 kg per person in the United States. According to a recent unpublished report by NMFS marketing specialists who visited western Europe, Belgian consumers tend to prefer salmon, herring, tuna, shrimp, mackerel, eels, crab, lobster, and mussels. None are fished extensively by Belgian fishermen (Table 3). Conversely, none of the species that are predominantly fished by the Belgian fleet (cod, sole, saithe, and plaice) are

[1]From "Fisheries of the United States, 1978," and based on live weight equivalents of fish consumed. Actual per capita consumption would be less, i.e., actual 1978 U.S. per capita consumption was about 7 kg.

Table 1.—Belgium's fisheries catch and imports and exports of edible fishery products, 1973-1978, in metric tons[1].

Year	Catch[2]	Imports[3]	Exports[3]
1973	46,305t	105,800t	27,400t
1974	41,995	112,100	23,700
1975	43,027	101,400	21,500
1976	44,501	113,311	24,000
1977	45,366	112,129	22,200
1978	50,893	105,436	24,631

[1]Belgium imported 32,000-34,000 t of fish meal annually during 1976-1978. Belgian fish meal exports rose from 2,000 t in 1976 to over 6,000 t in 1978.
[2]Live weight.
[3]Product weight.
Source: OECD Review of Fisheries.

Table 2.—Fishing fleets, 1976[1].

	Vessels	
Country	No.	GRT
United Kingdom	630	230,776
France	607	201,718
Germany	151	141,069
Italy	247	91,822
Netherlands	389	88,819
Denmark	358	69,009
Belgium	89	13,592
Ireland	27	13,592

[1]Only vessels 100 GRT or more.
Source: Lloyd's Register of Shipping, 1976.

Table 3.—Belgium's fish catch by species and landed weight, 1974-1978.

	Catch (in metric tons)				
Species	1974	1975	1976	1977	1978
Fish					
Demersal					
Plaice	6,397	6,277	5,934	8,008	6,887
Sole	2,660	2,763	3,415	3,277	2,960
Cod	10,739	8,659	9,296	12,109	19,498
Haddock	1,883	2,921	3,699	3,264	2,146
Saithe	2,265	1,544	1,875	1,564	1,145
Whiting	3,087	3,266	3,145	3,537	3,535
Redfish	1,992	1,671	1,524	1,396	1,549
Skate	1,582	1,485	1,753	1,517	1,612
Others	7,679	8,382	7,806	7,474	8,726
Total	38,284	23,973	38,447	42,146	48,062
Pelagic					
Herring	603	2,371	1,445	57	1
Sprat	34	—	—	—	—
Others	183	185	322	66	26
Total	820	2,556	1,767	123	27
Total, fish	39,104	39,529	40,214	42,289	48,089
Shellfish					
Norway lobster	426	434	448	474	854
Shrimp	1,322	1,617	2,093	1,236	591
Others	1,143	1,447	1,746	1,387	1,359
Total	2,891	3,498	4,287	3,097	2,804
Grand Total	41,995	43,027	44,501	45,366	50,893

among the products Belgians prefer. Therefore, Belgian fishery markets rely heavily on imports of fishery products to satisfy domestic demand.

Most fish are consumed fresh in Belgium, reflecting the relatively conservative consumption patterns of Belgian consumers. About 90 percent of the 1978 catch was marketed fresh, as well as about 27 percent of all imports (Table 4). Although consumption of frozen products accounted for only 6 percent of the domestic catch, it accounted for 24 percent of the much larger quantity of fish imported in 1978. Consumption of frozen products has been increasing in recent years, especially due to the growth of supermarket chains.

International Trade

Belgians rely heavily on international trade for their total fisheries supply. Imports, which supply approximately two-thirds of this total increase or decrease as the domestic catch falls or rises, respectively. Imports of edible fishery products in Belgium have fluctuated between 101,000 and 113,000 t annually since 1973 (Table 1). In addition, Belgium imported over 30,000 t annually of fish meal during 1976-78. The commodities imported in the largest quantities during 1977 were fish meal, mussels, cod, herring, and mackerel, while the most important Belgian fishery imports by value were shrimp, oysters, and crab.

Belgium's most important suppliers of fishery commodities are other EEC member countries. In 1977, approximately 83 percent of total imports came from those countries, primarily the Netherlands and Denmark. U.S. exports to Belgium constitute only a small portion of total Belgian fishery imports. In 1977, the U.S. exported only 2,800 t of fishery products to Belgium, valued at $12.6 million. Of this total, approximately half was frozen and canned salmon. The remainder consisted principally of fresh or chilled eels, canned crab, and fresh or frozen king crab (Table 5). Since most Belgian imports originate from other EEC countries, U.S. exports are usually competing with those countries' fishery exports. However, U.S. exports of salmon, by far the most important U.S. fishery export to Belgium, compete mainly with Canadian products.

Belgian exports of edible fishery products were 24,000 t in 1978, a slight increase over 1977 shipments of 22,000 tons. Fish meal exports remained stable at just over 6,000 t during this period. Most exports go to other EEC countries, especially France. Approximately one-third of all Belgian fishery exports consist of cod, whiting, and plaice. Belgian companies have no plans to promote export sales because of the country's small catch and large demand for fishery products.

In response to a number of complaints from European countries regarding the quality of U.S. fishery exports, NMFS officials met with government and industry representatives from several European countries in April 1978. The discussions covered a variety of problems dealing with U.S. fishery exports to western European countries. The main problem cited by the Belgian participants was that markets in that country require unusually high quality fishery products. The Belgian companies import nearly four times more salmon from Canada than from the United States (Table 5). According to the Belgians, the quality of the Canadian products is superior. A spokesman for the U.S. canned salmon industry has indicated, however, that a significant difference in quality between U.S. and Canadian canned salmon is unlikely, since both countries use the same varieties of salmon and the same processing techniques.

Another more general concern expressed by Belgian importers to NMFS officials at the April 1978 meeting was that little is known about the safety and quality standards of U.S. fishery commodities. NMFS representatives recommended that an effort be made to familiarize the appropriate government and corporate officials with the NMFS Fishery Inspection Service, since most of the European participants at the April meetings indicated that they were unaware of its existence. U.S. exporters are encouraged to utilize the NMFS Fishery Inspection Service.

Still another problem is that European importers are not well informed as to what species are available from U.S. exporters, and in what product form. NMFS representatives suggested that this problem could best be solved by increasing contacts between U.S. exporters and potential Belgian buyers.

Belgian health regulations require that U.S. fishery imports be accompanied by both of the following documents: A lot inspection certificate (NOAA form 89-803) and a certificate of wholesomeness (NOAA form 89-845). These certificates are required for imported fresh, chilled, frozen, or canned fish, but not for imports of marinated fish products or semi-preserved fish in sauces. (Source: IFR-79/83).

Table 4.—Belgian utilization of fish by commodity (in metric tons and percentage of total), 1978.

Product	Domestic catch		Imports		Total supply	
	Quantity	Percent	Quantity	Percent	Quantity	Percent
Fresh	40,841	90.1	37,200	26.7	78,041	42.3
Frozen	2,720	6.0	33,400	24.0	36,120	19.6
Canned	680	1.5	30,900	22.2	31,580	17.0
Cured	—	—	3,970	2.8	3,970	2.2
Fish meal	1,088	2.4	33,800	24.3	34,888	18.9
Total	45,329	100.0	139.270	100.0	184,599	100.0

Source: OECD Review of Fisheries, 1978.

Table 5.—Belgium's principal fishery imports from the United States, 1977.

Commodity	Total Belgian imports (t)	Major supplier		U.S. exports	
		Country	Quantity (t)	Quantity (t)	Value (US$ 1,000)
Fresh, chilled eels	1,826	EEC	995	596	2,077
Frozen salmon	1,860	U.S.	930	930	4,920
Frozen king crab	n.a.[1]	n.a.	n.a.	220	2,873
Canned salmon	3,460	Canada	1,90[illegible]	442	1,325
Canned crabs	1,142	EEC	274	271	3,149

[1]n.a.=not available.

Source: Bulletin Mensual du Commerce Exterieur de L'Union Economique Belgo-Luxembourgeoise, Dec. 1977, and Fisheries of the United States, 1977.

Aquaculture: Principles, Practices, and Disease Controls Are Published

"Principles of Warmwater Aquaculture" by Robert R. Stickney, has been published by John Wiley and Sons, Inc. as an introductory text. As such, it examines various subject areas of aquaculture and provides concepts and techniques needed to rear warmwater species in both fresh and marine conditions and under controlled or semi-controlled conditions.

Stickney, Associate Professor in the Department of Wildlife and Fisheries Sciences at Texas A&M University, covers the topic in nine chapters, beginning with basic definitions and an overview of fish culture in Chapter 1. Other chapters discuss water systems; nonconservative aspects of the aquatic environment; feeds, nutrition, and growth; reproduction, selective breeding, and genetics; disease and parasitism; harvesting, processing, and economics; and minnow, goldfish, centrarchid, and striped bass culture.

Each chapter contains an extensive listing of cited literature as well as suggested additional reading material. A glossary defines terms important to aquaculturists. The book costs $22.50 and is available from John Wiley and Sons, 605 3rd Avenue, New York, NY 10016.

The second edition of **"Fish and Invertebrate Culture"** subtitled "Water management in closed systems" by Stephen Spotte, Director, Mystic Marinelife Aquarium, has also been printed by John Wiley and Sons. Unlike its title implies, the volume discusses water quality control in closed-system fresh, brackish, and seawater environments; it does not specifically address the rearing of aquatic animals.

Chapter topics include: Biological and mechanical filtration processes, removal of dissolved organic carbon, methods of disinfection, gas exchange and respiration by aquatic animals, seawater, buffering, toxicity and disease prevention, and aquarium water analytical methods. The text has been updated and rewritten, dealing with applicable theoretical and practical subjects. A new section, "Management Practices," has been added to the end of each chapter. The 179-page volume costs $13.95.

"Aquacultural Engineering" by Frederick W. Wheaton, also published by Wiley, is a state-of-the-art presentation of the technical engineering facets of aquaculture, fisheries, and other aquatic systems. It presents information for putting scientific knowledge into practical and economically feasible systems for producing cultured aquatic crops. Part I discusses how aquatic environmental conditions influence organisms and relates how the organisms adjust to changing environments. Part II describes how to create a desirable aquatic environment. Engineering concepts are applied to the production of aquatic species in fresh, brackish, and seawater. The 708-page volume costs $38.95.

"Handbook of Drugs and Chemicals Used in the Treatment of Fish Diseases" by Nelson Herwig, is subtitled "A manual of fish pharmacology and materia medica." The 272-page volume is published by Charles C. Thomas, 301-327 East Lawrence Avenue, Springfield, IL 62717 and costs $17.50. The author is curator of fishes at the Houston Zoological Gardens, Houston, Tex.

This text provides an extensive list of pharmaceuticals applicable to fish medicine. Part I, "Fish pharmacology" presents chapters on therapeutics in fish diseases, drug therapy, actions and uses of drugs, and toxicology. Part II, "Materia medica" contains an alphabetical annotated listing of drugs and their synonyms ranging from acetarsol to zonite plus doses and treatments, along with remarks and references.

An extensive bibliography is included as are appendices listing viricides, bactericides, algicides, fungicides, protozoacides, anthelminthics, crustacides, insecticides, molluscicides, fish toxicants, disinfectants, fish anaesthetics and tranquilizers, antiseptics, and more. A partial listing of manufacturers and/or distributors of drugs and chemicals is also listed in the text. The volume should be very useful to those dealing with fish disease treatments.

Phytoplankton Manual and Sediment Report Printed

"Phytoplankton Manual" is the sixth of the UNESCO Division of Marine Sciences' monographs on oceanographic methods issued in conjunction with the Scientific Committee on Oceanographic Research (SCOR) in the last 13 years. It covers the quantitative study of phytoplankton from initial planning through interpretation of the results.

The 337-page volume presents 50 contributions by specialists in the following sections: Sampling design and techniques, preservation and storage, concentrating phytoplankton, identification problems, estimating cell numbers, interpreting the observations, and comments on related fields (bacterioplankton, microzooplankton, freshwater phytoplankton).

The Division has also published **"Biogeochemistry of Estuarine Sediments,"** a 293-page, 8¼" × 10½" soft bound volume of the proceedings of a workshop held in Melreux, Belgium, from 29 November to 3 December 1976. It includes contributions on four basic research themes as well as workshop reports which underscore future priorities in estuarine research.

The papers presented are published as four Group Reports: 1) "Forms and species of dissolved elements in estuarine systems"; 2) "Forms and species of particulars in estuarine systems"; 3) "Transfer processes between the water and sediment"; and 4) "The role of organisms in estuarine sedimentation processes". Both volumes are available from Unipub, 345 Park Avenue South, New York, NY 10010. The Phytoplankton Manual costs $18.50 and Biogeochemistry of Estuarine Sediments costs $15.50.

Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Citations

Title the list of references "Literature Citations" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, the year and month and volume and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 1107 N.E. 45th Street, Room 450, Seattle, WA 98105.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 100 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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